01 SOLID FUELS

Sources, winning, properties

10/00480 Critical evaluation of sequential extraction and sink-float methods used for the determination of Ga and Ge affinity in lignite

Klika, Z. *et al*. *Fuel*, 2009, 88, (10), 1834–1841.

The affinities of Ga and Ge in lignite were determined using sequential extraction (SE) and element affinity calculation (EAC) based on sink-float data. For this study a bulk lignite sample was fractioned into two sets. The first set of samples (A) consisted of the different grain sizes fractions; the second one set (B) was prepared by density fractionation. Sequential extractions were performed on both sets of fractions with very good agreement between determined organic elements affinities (OEA of Ga evaluated from A data is 32%, from B data 35%; OEA of Ge evaluated from A data is 31% and from B data 26%). The data of B lignite fractions were evaluated using two element affinity calculations: (a) EAC (I) of Klika and Kolomazník and (b) the newly prepared subroutine EAC (II) based on quantitative contents of lignite macerals and minerals. There was also good agreement between both methods obtained (OEA of Ga calculated by EAC (I) is 83% and by EAC (II) 77%; OEA of Ge calculated by EAC (I) is 89% and by EAC (II) 97%). The significant differences of organic elements affinities of Ga and Ge evaluated by sequential extraction and by element affinity calculation based on sink-float data are discussed.

10/00481 Effect of pre-swelling of coal at mild temperatures on its hydro-liquefaction properties

Shui, H. *et al*. *Fuel Processing Technology*, 2009, 90, (7–8), 1047–1051.

The effects of pre-swelling treatment of Shenhua coal at mild temperatures (less than 160 °C) on its hydro-liquefaction properties were determined in this paper. It was found that with the increase of pre-swelling temperature in tetralin (THN) up to 120 °C, the liquefaction conversions of swollen coals increased. However, when *N*-methyl-2-pyrrolidinone (NMP) was used as swelling solvent, the liquefaction conversion decreased with the increase of pre-swelling temperature. The liquefied product distributions were very much dependent on the pre-swelling pretreatment conditions, and the mechanism was discussed. Based on the results obtained, a new swelling-liquefaction combining technology (SLCT) was advanced, in which the liquefaction conversion and oil + gas yield were enhanced.

10/00482 Numerical simulation of the devolatilization of a moving coal particle

Higuera, F. J. *Combustion and Flame*, 2009, 156, (5), 1023–1034.

The devolatilization of an isolated coal particle moving relative to the surrounding gas is numerically simulated using a competing reaction model of the pyrolysis and assuming that the released volatiles burn in an infinitely thin diffusion flame around the particle or not at all. The temperature of the particle is assumed to be uniform and the effects of the heat of pyrolysis, the intraparticle mass transfer resistance, and the variation of the particle radius are neglected. The effects of the size and velocity of the particle and of the temperature and oxygen mass fraction of the gas on the particle and flame temperature histories, the devolatilization time and the yield of light and heavy volatiles are investigated. The motion of the particle may have an important effect on the shape and position of the flame of volatiles, but it has only a mild effect on the devolatilization process for the particle sizes typical of pulverized coal combustion. This effect increases for large particles or in the absence of radiation. The relative motion enhances the heat transfer between the particle and the gas, causing the devolatilization time to decrease at high gas temperatures and to increase at low gas temperatures. The numerical results are compared with a blowing-corrected Nusselt number correlation often used in heat transfer models of the process.

10/00483 Origin of natural waters and gases within the Upper Carboniferous coal-bearing and autochthonous Miocene strata in South-Western part of the Upper Silesian Coal Basin, Poland

Kotarba, M. J. and Pluta, I. *Applied Geochemistry*, 2009, 24, (5), 876–889.

The molecular and stable isotope compositions of coalbed gases from the Upper Carboniferous strata and natural gases accumulated within the autochthonous Upper Miocene Skawina Formation of the Dębowiec-Simoradz gas deposit were determined, as well as the chemical and stable isotope compositions of waters from the Skawina Formation and waters at the top of the Upper Carboniferous strata of the Kaczyce Ridge (the abandoned ‘Morcinek’ coal mine) in the South-Western part of the Upper Silesian Coal Basin. Two genetic types of natural gases within the Upper Carboniferous coal-bearing strata were identified: thermogenic (CHM_4, small amounts of higher gaseous hydrocarbons, and CO_2) and microbial (CH_4, very small amounts of ethane, and CO_2). Thermogenic gases were generated during the bituminous stage of coalification and completed at the end of the Variscan orogeny. Degassing (desorption) of thermogenic gases began at the end of late Carboniferous until the late Miocene time-period and extended to the present-day. This process took place in the Upper Carboniferous strata up to a depth of about 550 m under the sealing Upper Miocene cover. A primary accumulation zone of indigenous, thermogenic gases is present below the degassing zone. Up to 200 m depth from the top of the Upper Carboniferous strata, within the weathered complex, an accumulation zone of secondary, microbial gas occurs. Waters within these strata are mainly of meteoric origin of the infiltration period just before the last sea transgression in the late Miocene and partly of marine origin having migrated from the Upper Miocene strata. Then, both methanogenic archaebacteria and their nutrients were transported by meteoric water into the near-surface Carboniferous strata where the generated microbial CH_4 saturated coal seams. Waters within the Miocene strata of the Dębowiec-Simoradz and Zablocie are of marine origin, and natural gases accumulated within autochthonous Miocene strata of the Dębowiec-Simoradz gas deposit were most probably generated by microbial processes of on organic matter dispersed within the strata, though some contribution of gases migrating from the Carboniferous coal-bearing strata cannot be excluded.

10/00484 Quenched solid density functional theory and pore size analysis of micro-mesoporous carbons

Neimark, A. V. *et al*. *Carbon*, 2009, 47, (7), 1617–1628.

This study presents a new model of adsorption on micro-mesoporous carbons based on the quenched solid density functional theory (QSDFT). QSDFT quantitatively accounts for the surface geometrical inhomogeneity in terms of the roughness parameter. The suthors developed the QSDFT models for pore size distribution calculations in the range of pore widths from 0.4 to 35 nm from nitrogen at 77.4 K and argon at 87.3 K adsorption isotherms. The QSDFT model improves significantly the method of adsorption porosimetry: the pore size distribution (PSD) functions do not possess gaps in the regions of ~1 nm and ~2 nm, which are typical artifacts of the standard non-local density functional theory (NLDFT) model that treats the pore walls as homogeneous graphite-like plane surfaces. The advantages of the QSDFT method are demonstrated on various carbons, including activated carbons fibres, coal based granular carbon, water purification adsorbents, and mirco-mesoporous carbon CMK-1 templated on MCM-48 silica. The results of PSD calculations from nitrogen and argon are consistent, however, argon adsorption provides a better resolution of micropore sizes at low vapour pressures than nitrogen adsorption.

Preparation

10/00485 On the adequacy of distribution curves used in coal cleaning – a statistical analysis

Mohanta, S. and Mishra, B. K. *Fuel*, 2009, 88, (11), 2262–2268.

The performance of a gravity separator treating coal is commonly determined by plotting a Tromp curve which is basically a plot of partition coefficients against average specific gravity. There are many mathematical models proposed in the literature to represent this curve but selecting the most appropriate model for a given application is not straightforward. As the model is always tentative, it is necessary to examine the adequacy of the model for a particular process. To ascertain the adequacy and the reliability of a model, the authors consider six different mathematical models available in the literature and determine their suitability for representing the water-only cyclone data. The best model is selected in three steps by adopting a statistical analysis approach.

10/00486 Premixed ignition behavior of C_9 fatty acid esters: a motored engine study

Zhang, Y. *et al*. *Combustion and Flame*, 2009, 156, (6), 1202–1213.

An experimental study on the premixed ignition behaviour of C_9 fatty acid esters has been conducted in a motored CFR engine. For each test fuel, the engine compression ratio was gradually increased from the lowest point (4.43) to the point where significant high temperature heat release (HTHR) was observed. The engine exhaust was sampled and analysed through GC-FID/TCD and GC-MS. Combustion analysis showed that the four C_9 fatty acid esters tested in this study exhibited evidently different ignition behaviour. The magnitude of low temperature heat release (LTHR) follows the order, ethyl nonanoate > methyl nonanoate ≫ methyl 2-nonenoate > methyl 3-nonenoate. The lower oxidation reactivity for the unsaturated fatty acid esters in the low temperature regime can be explained by the reduced amount of six- or seven-membered transition state rings formed during the oxidation of the unsaturated esters due to the presence of a double bond in the aliphatic chain of the esters. The inhibition effect of the double bond on the low temperature oxidation reactivity of fatty acid esters becomes more pronounced as the double bond moves toward the central position of the aliphatic chain. GC-MS analysis of exhaust condensate collected under the engine conditions where only LTHR occurred showed that the alkyl chain of the saturated fatty acid esters participated in typical paraffin-like low temperature oxidation sequences. In contrast, for unsaturated fatty acid esters, the autoignition can undergo olefin ignition pathways. For all test compounds, the ester functional group remains largely intact during the early stage of oxidation.

10/00487 Solid fuels in chemical-looping combustion using oxide scale and unprocessed iron ore as oxygen carriers

Leion, H. *et al. Fuel*, 2009, 88, (10), 1945–1954.

Chemical-looping combustion (CLC) is a novel technology that can be used to meet demands on energy production without CO_2 emissions. The CLC-process includes two reactors, an air and a fuel reactor. Between these two reactors oxygen is transported by an oxygen carrier, which most often is a metal oxide. This arrangement prevents mixing of N_2 from the air with CO_2 from the combustion. The combustion gases consist almost entirely of CO_2 and H_2O. Therefore, the technique reduces the energy penalty that normally arises from the separation of CO_2 from other flue gases, hence, CLC may make capture of CO_2 cheaper. Iron ore and oxide scale from steel production were tested as oxygen carriers in CLC batch experiments with solid fuels. Petroleum coke, charcoal, lignite and two bituminous coals were used as fuels. The experiments were carried out in a laboratory fluidized-bed reactor that was operating cyclically with alternating oxidation and reduction phases. The exhaust gases were led to an analyser where the contents of CO_2, CO, CH_4 and O_2 were measured. Gas samples collected in bags were used to analyse the content of hydrogen in a gas chromatograph. The results showed that both the iron ore and the oxide scale worked well as oxygen carrier and both oxygen carriers increased their reactivity with time.

Economics, business, marketing, policy

10/00488 Burning peat in Ireland: an electricity market dispatch perspective

Tuohy, A. *et al. Energy Policy*, 2009, 37, (8), 3035–3042.

This paper examines peat power production in Ireland under the three pillars of energy policy – security, competitiveness and environment. Peat contributes to energy security – as an indigenous fuel, it reduces dependency on imports. During a period of low capacity margins, the operation of the peat plants is useful from a system security perspective. Peat generation is being financially supported by consumers through an electricity levy. The fuel also has high carbon intensity. It is not politically viable to consider peat on equal economic criteria to other plant types because of history and location. This paper reviews electricity generation through combustion of peat in Ireland, and quantifies the costs of supporting peat utilizing economic dispatch tools, finding the subsidy is not insignificant from a cost or carbon perspective. It shows that while peat is beneficial for one pillar of energy policy (security), the current usage of peat is not optimal from a competitiveness or environmental perspective. By switching from the current 'must-run' mode of operation for peat to the 'dispatched' mode used for the other generation, significant societal savings (in the range €21 million per annum) can be achieved, as well as reducing system emissions by approximately 5% per year.

10/00489 Climate change and energy policies, coal and coalmine methane in China

Yang, M. *Energy Policy*, 2009, 37, (8), 2858–2869.

The Chinese government has made many energy policies on coal, and coalmine methane (CMM) use. However, not all of these policies have effects or positive impacts. For example, it has been quite a few years since the national government made policies to encourage coalmine methane power to be sold to the grid. Practice showed that not any kilowatt of electricity was sold from a coalmine methane power plant to the grid in Sichuan and Guizhou Provinces as of December 2008. The objectives of this paper are to review and evaluate the Chinese government energy and climate policies that are related to coal and coalmine methane, analyse relevant policy barriers, and make recommendations to overcome these barriers and avoid policy failures. This paper provides the literature review, challenges, resources, policies and other updated information on China's CMM recovery and utilization. The paper concludes that China needs to further reform its energy and environment management system, engage provincial governments in CMM capture and use activities, and provide incentives to qualified engineers and skilled workers to work in remote coal mining areas. This paper transfers key messages to policy makers for them to make better CMM capture and use policies.

10/00490 Coal and energy security for India: role of carbon dioxide (CO_2) capture and storage (CCS)

Garg, A. and Shukla, P. R. *Energy*, 2009, 34, (8), 1032–1041.

Coal is the abundant domestic energy resource in India and is projected to remain so in future under a business-as-usual scenario. Using domestic coal mitigates national energy security risks. However coal use exacerbates global climate change. Under a strict climate change regime, coal use is projected to decline in future. However this would increase imports of energy sources like natural gas and nuclear and consequent energy security risks for India. The paper shows that carbon dioxide (CO_2) capture and storage (CCS) can mitigate CO_2 emissions from coal-based large point source (LPS) clusters and therefore would play a key role in mitigating both energy security risks for India and global climate change risks. This paper estimates future CO_2 emission projections from LPS in India, identifies the potential CO_2 storage types at aggregate level and matches the two into the future using Asia-Pacific Integrated Model (AIM/Local model) with a geographical information system interface. The paper argues that clustering LPS that are close to potential storage sites could provide reasonable economic opportunities for CCS in future if storage sites of different types are further explored and found to have adequate capacity. The paper also indicates possible LPS locations to utilize CCS opportunities economically in future, especially since India is projected to add over 220,000 MW of thermal power generation capacity by 2030.

10/00491 Forecasting coal production until 2100

Mohr, S. H. and Evans, G. M. *Fuel*, 2009, 88, (11), 2059–2067.

A model capable of projecting mineral resources production has been developed. The model includes supply and demand interactions, and has been applied to all coal producing countries. A model of worldwide coal production has been developed for three scenarios. The ultimately recoverable resources (URR) estimates used in the scenarios ranged from 700 Gt to 1243 Gt. The model indicates that worldwide coal production will peak between 2010 and 2048 on a mass basis and between 2011 and 2047 on an energy basis. The best-guess scenario, assumed a URR of 1144 Gt and peaks in 2034 on a mass basis, and in 2026 on an energy basis.

10/00492 Greenhouse gas implications of using coal for transportation: life cycle assessment of coal-to-liquids, plug-in hybrids, and hydrogen pathways

Jaramillo, P. *et al. Energy Policy*, 2009, 37, (7), 2689–2695.

Using coal to produce transportation fuels could improve the energy security of the United States by replacing some of the demand for imported petroleum. Because of concerns regarding climate change and the high greenhouse gas (GHG) emissions associated with conventional coal use, policies to encourage pathways that utilize coal for transportation should seek to reduce GHGs compared to petroleum fuels. This paper compares the GHG emissions of coal-to-liquid (CTL) fuels to the emissions of plug-in hybrid electric vehicles (PHEV) powered with coal-based electricity, and to the emissions of a fuel cell vehicle (FCV) that uses coal-based hydrogen. A life cycle approach is used to account for fuel cycle and use-phase emissions, as well as vehicle cycle and battery manufacturing emissions. This analysis allows policymakers to better identify benefits or disadvantages of an energy future that includes coal as a transportation fuel. The study found that PHEVs could reduce vehicle life cycle GHG emissions by up to about one-half when coal with carbon capture and sequestration is used to generate the electricity used by the vehicles. On the other hand, CTL fuels and coal-based hydrogen would likely lead to significantly increased emissions compared to PHEVs and conventional vehicles using petroleum-based fuels.

10/00493 Minimizing activated carbons production cost

Stavropoulos, G. G. and Zabaniotou, A. A. *Fuel Processing Technology*, 2009, 90, (7–8), 952–957.

A detailed economic evaluation of activated carbons production process from various raw materials is undertaken using the conventional economic indices (ROI, POT, and NPV). The fundamental factors that affect production cost were taken into account. It is concluded that for an attractive investment in activated carbons production one should select the raw material with the highest product yield, adopt a chemical activation production scheme and should base product price on product-surface area (or more generally on product adsorption capacity for the adsorbate in consideration). A raw material that well meets the above-mentioned criteria is petroleum coke but others are also promising (charcoals, and carbon black). Production cost then can be optimized by determining its minimum value of cost that results from the intercept between the curves of plant capacity and raw material cost – if any. Taking into account the complexity of such a techno-economic analysis, a useful suggestion could be to start the evaluations from a plant capacity corresponding to the break-even point, i.e. the capacity at which income equals production cost.

10/00494 Sustainable development of the Indian coal sector

Chikkatur, A. P. *et al. Energy*, 2009, 34, (8), 942–953.

Increased availability of energy, especially electricity, is important for India to help advance economic and human development. Coal, which currently accounts for more than 50% of total primary commercial energy supply in the country and for about 70% of total electricity generation, is likely to remain a key energy source for India for at least the next 30–40 years. Thus, sustainable development of the Indian coal sector is necessary to ensure the ability to sustain the increased production of coal in the country and to do so in an environmentally and socially sustainable manner. The main challenges to such a development of the coal sector pertain to (a) systems of coal exploration, extraction, and processing, (b) ensuing environmental and social concerns, and (c) increasing and high demand for coal in the power sector. Overcoming these challenges will require an assessment and resolution of relevant technical, economic, and institutional issues. This, in turn, requires a long-term vision and systematic planning and policy development in a transparent and inclusive manner. Promoting the engagement of all stakeholders in these processes can help reconcile the seemingly intractable conflict between the increasing demand for coal, supply constraints, and local socio-environmental needs, and thus facilitate a transition towards sustainable development of the sector.

Derived solid fuels

10/00495 Carbon nanofibers as electrocatalyst support for fuel cells: effect of hydrogen on their properties in CH_4 decomposition

Sebastián, D. *et al. Journal of Power Sources*, 2009, 192, (1), 51–56.

The influence of low partial pressure of hydrogen on carbon nanofibres (CNFs) properties has been studied in the synthesis by methane catalytic decomposition, with the purpose of using them in polymer electrolyte fuel cells as electrocatalyst support. Using CNFs in this kind of application presents a good perspective to improve the fuel cell overall performance. CNF growth in the catalytic decomposition of methane and the characteristics which are typically required in a carbonaceous support, are influenced by hydrogen concentration, which has been studied at different temperatures. The textural, morphological and structural characteristics of the obtained CNFs have been determined by nitrogen physisorption, X-ray diffraction, electron microscopy and thermogravimetry. Electrical conductivity of CNFs has been measured compressing the powder and using a two-probe method. It was observed that low values of partial pressure of hydrogen in methane influence positively structural ordering of CNFs, and in turn improve electrical conductivity, with a slight influence on textural properties leading to highly mesoporous carbon.

10/00496 Charcoal from biomass residues of a *Cryptomeria* plantation and analysis of its carbon fixation benefit in Taiwan

Lin, Y.-J. and Hwang, G.-S. *Biomass and Bioenergy*, 2009, 33, (9), 1289–1294.

Charcoal production as an age-old industry not only supplies fuel in developing countries, in recent decades, it has also become a means of supplying new multifunctional materials for environmental improvement and agricultural applications in developed countries. These include air dehumidification and deodorization, water purification, and soil improvement due to charcoal's excellent adsorption capacity. Paradoxically, charcoal production might also help curb greenhouse gas emissions. In this study, charcoal was made from discarded branches and tops of wood from a *Cryptomeria* plantation after thinning using a still-operational earthen kiln. Woody biomass was used as the carbonization fuel. The effect of carbonization on carbon fixation was calculated and its benefits evaluated. The results showed that the recovered fixed carbon reached 33.2%, i.e. one-third of the biomass residual carbon was conserved as charcoal which if left on the forest ground would decompose and turn into carbon dioxide, and based on a net profit of US\$1.13 kg^{-1} for charcoal, an annual net profit of US\$14,665 could be realized. Charcoaling thus appears to be a feasible alternative to promote reutilization of woody resides which would not only reduce greenhouse gas emissions, but also provide potential benefits to regional economies in developing countries.

10/00497 Comparative study of fluorinated single- and few-wall carbon nanotubes by X-ray photoelectron and X-ray absorption spectroscopy

Lavskaya, Y. V. *et al. Carbon*, 2009, 47, (7), 1629–1636.

Pristine and ball-milled samples containing single-wall carbon nanotubes (SWCNTs) and few-wall carbon nanotubes (FWCNTs) have been fluorinated at room temperature using gaseous BrF_3 as a fluorinating agent. X-ray photoelectron spectroscopy (XPS) and near-edge X-ray absorption fine structure (NEXAFS) spectroscopy were used to estimate the chemical composition and to probe the electronic structure of the fluorinated CNTs. Analysis of the XPS C 1s spectra revealed that fluorinated carbon atoms in SWCNTs are bounded with one CF-group at least while most of the fluorinated carbon atoms in FWCNTs are surrounded by bare carbon atoms only. The ball-milling of the samples during 1 hour has insignificant effect on CNT length and more likely produces defects in CNT surface layers. These defects increase fluorination ability of CNTs and provide access for fluorine atoms to the subsurface layers of FWCNTs. NEXAFS investigation revealed that some of CNTs, which probably constitute interior of FWCNTs or CNT ropes, are not fluorinated during the conditions used and the fluorine atoms interact more strongly with CNT surfaces having a larger curvature.

10/00498 Effect of temperature on the reaction of H_2S with a coke

Zhou, S. *et al. Fuel Processing Technology*, 2009, 90, (7–8), 679–882.

The effect of temperature on reaction of H_2S with carbon structures of a coke were studied in a fixed-bed quartz tube reactor coupled with two parallel detectors, flame photometric detector (FPD) and mass spectrum (MS). The uptake of H_2S with the coke matrix was studied through a sulfur uptake/temperature programmed desorption process (SU/TPD) and a temperature programmed oxidation process (TPO). The results show that the sulfur imbibed by a demineralized coke at elevated temperatures is very stable, which can only be decomposed and released to gas phase under combustion conditions. The chemical imbibition of sulfur takes place at an elevated temperature. At relatively lower temperatures, H_2S was adsorbed physically by the sample and then transformed to stable sulfur species. At higher temperatures, the chemical reactions between H_2S and DM-coke led to the formation of more stable sulfur-containing forms and consequently increased H_2S uptake ability. This is essence of the temperature effect on the uptake of H_2S by a demineralized coke. The irregular behaviour with the temperature was caused by the different interactions.

10/00499 Effects of physical properties on one-dimensional downward smoldering of char: numerical analysis

He, F. *et al. Biomass and Bioenergy*, 2009, 33, (8), 1030–1036.

Smoldering combustion in a packed bed of carbonaceous material is a very complex process, where numerous physical and chemical parameters are involved. This study was conducted to examine the impact of several physical parameters on the behaviour of natural downward smoldering. For that purpose, a one-dimensional homogeneous model has been developed. Due to the fact that drying, pyrolysis or oxidative degradation occurs significantly faster than carbon oxidation, only the latter phenomenon was taken into account. The model was evaluated by comparison of numerical simulation results with experimental observations. Sensitivity analysis calculations of different physical properties of the bed material with respect to smoldering time, smoldering front velocity and front temperature suggest that in future experiments special attention should be devoted to accurate determination of bed shrinkage, bulk carbon density, mean void size, oxygen diffusivity in fuel bed.

10/00500 Needle coke formation derived from co-carbonization of ethylene tar pitch and polystyrene

Cheng, X. *et al. Fuel*, 2009, 88, (11), 2188–2192.

Ethylene tar pitch was co-carbonized with waste polystyrene to prepare needle coke. The modified properties of mesophase, which were greatly improved due to increasing naphthenic and other alkyl content, availed the formation of needle coke with high quality. The coefficient of thermal expansion value was decreased from $3.2 \times 10^{-6}/°C$ to $0.3 \times 10^{-6}/°C$ and the optical texture of the coke was changed from coarse mosaic texture to flow domain of high uniaxial orientation after adding waste polystyrene into ethylene tar pitch. The low viscosity of the mesophase pitches favored the development of mesophase and highly uniaxial arrangement. The increase in alkyl group content greatly improved characteristics of the needle coke.

10/00501 Potential applicability of CNT and CNT/composites to implement ASEC concept: a review article

Wijewardane, S. *Solar Energy*, 2009, 83, (8), 1379–1389.

This study evaluates carbon nanotubes (CNTs), known as the material of the twenty-first century, in terms of the Antenna Solar Energy Conversion (ASEC) concept. It was found that CNTs provide exceptional thermo-mechanical properties that suit ASEC. The outcomes from the research on the interaction of visible light with single walled CNT (SWCNT) and CNT arrays favour the manufacturing of optical antennas with CNT. High frequency diodes with CNT are becoming a reality. Nevertheless intense research has to be focused to obtain the optimistic high efficiencies. CNT-related technologies have the potential to enhance the progress of the ASEC concept but most of technologies are in their initial stages and would need some time to improve to the commercial level. However, carbon nanotubes provide a potential solution to the energy problems facing the world today.

10/00502 The low-temperature SCR of NO over rice straw and sewage sludge derived char

Cha, J. S. *et al. Chemical Engineering Journal*, 2009, 156, (2), 321–327.

Rice straw char and sewage sludge char were applied as catalysts for selective catalytic reduction between 50 and 250 °C using ammonia as the reducing agent. Each char was activated physically, using water vapour, or chemically, using KOH. The characteristics of the prepared catalysts were analysed through elemental analysis, N_2 adsorption–desorption, FT-IR, NO-TPD, NH_3-TPD, and NO_x removal efficiency. The physically activated chars showed characteristics similar to those of the non-activated chars, whereas the chemically activated chars exhibited increased specific surface areas, pore volumes, NO adsorption capacities, NH_3 adsorption capacities, and oxygen functional group amounts, leading to higher NO_x removal efficiency. When the catalysts were impregnated with 3 wt% manganese, NO_x removal efficiency significantly increased. In particular, the NO_x removal efficiency was highest when the chemically activated chars were impregnated with manganese.

10/00503 The optimum conditions for preparing solid fuel briquette of rice straw by a piston-mold process using the Taguchi method

Chou, C.-S. *et al. Fuel Processing Technology*, 2009, 90, (7–8), 1041–1046.

Using the Taguchi method, this study analysed the optimum conditions for preparing the solid fuel briquette of the rice straw by a piston-mold process. The controllable factors used in this study consisted of the following: (1) the type of binder (such as the rice bran, the soybean residue, and the sawdust of *Acacia confuse*), (2) the hot-pressing temperature (such as 110, 130, and 150 °C), (3) the size of the smashed rice straw (such as 10–5 mm, 5–2 mm, and < 2 mm), and (4) the percentage ratio of rice straw to binder in a briquette (such as 100/0, 80/20, and 60/40). The percentage contribution of each controllable factor was also determined. The confirmation experiment was carried out according to the optimum conditions. Most interestingly, the size of the smashed rice straw is the most influential factor to solidify fuel briquette, and its value is up to 43.0%.

10/00504 Transformations of pyrite during formation of metallurgical coke

Gornostayev, S. *et al. Fuel*, 2009, 88, (10), 2032–2036.

The desulfurization of pyrite during the coking process leads to the formation of phases of varying size, shape and composition. The phases are represented mostly by Fe and S-bearing associations, which can be divided into two categories: those represented only by of Fe–S phases (three varieties), and aggregates containing both sulfides and almost pure iron. There are also Fe–O and Fe–S–O phases, which were probably formed after the coke was pushed from the coke oven. It is suggested that the formation of Fe and S-bearing associations can cause the appearance of cracks and cavities in the coke matrix, which, together with the pressure of the released SO_2 gas, will detract from the strength of the coke. Large grains of pyrite can create weaker spots than do smaller ones, and the incomplete decomposition of pyrite will cause migration of the remaining part of the sulfur to the blast furnace, affecting the reactions there. This may be more common in cokes of relatively low porosity and small pore size and in those made from coals with large pyrite grains.

10/00505 XPS study and physico-chemical properties of nitrogen-enriched microporous activated carbon from high volatile bituminous coal

Pietrzak, R. *Fuel*, 2009, 88, (10), 1871–1877.

N-enriched microporous active carbons of different physico-chemical parameters have been obtained from high volatile bituminous coal subjected to the processes of ammoxidation, carbonization and activation in different sequences. Ammoxidation was performed by a mixture of ammonia and air at the ratio 1:3 (flow ratio 250 ml/min:750 ml/min) at 350 °C, at each stage of production i.e. that of precursor, carbonisate and active carbon. Ammoxidation performed at the stage of demineralized coal or carbonisate has been shown to lead to a significant nitrogen enrichment and to have beneficial effect on the porous structure of the carbon during activation, allowing obtaining samples of the surface area of 2600–2800 m^2/g and pore volume 1.29–1.60 cm^3/g to be obtained with the yield of about 50%. The amount of nitrogen introduced into the carbon structure was found to depend on the sequence of the processes applied. The greatest amount of nitrogen was introduced for the processes in the sequence carbonization → activation → ammoxidation. The introduction of nitrogen at the stage of active carbon leads to a reduction in the surface area and lowering of its sorption capacity. From the XPS study, ammoxidation introduces nitrogen mainly in the form of imines, amines, amides, N-5 and N-6, irrespective of the processing stage at which it is applied.

02 LIQUID FUELS

Sources, properties, recovery

10/00506 Autothermal reforming of diesel fuel in a structured porous metal catalyst: both kinetically and transport controlled reaction

Shigarov, A. B. *et al. Catalysis Today*, 2009, 144, (3–4), 341–349.

Autothermal reforming (ATR) of diesel fuel into syngas was studied experimentally and theoretically. The experiments were performed in a reactor consisting of two cylindrically shaped monoliths 50 × 55 mm. Different catalytically active components and supports (Co, Mn, Rh, BaO, La_2O_3/Al_2O_3 and SiO_2) were tested. The reactor parameters were as follows: $O_2/C = 0.5$, $S/C = 1.5–1.7$, $T_{in} = 350–400\,°C$. The regularly structured catalytic monoliths were prepared using various metal porous supports. The most active and coke resistant catalyst was determined. The original modelling approach was based on the assumption that ATR involves two parallel reaction routes: (1) complete hydrocarbon oxidation, (2) steam reforming of hydrocarbon. The experimental data and the results of reactor modelling agreed well and allowed a conclusion that the ATR rate is controlled by inter-phase mass transfer. However, the contribution of the reaction routes (1) and (2), i.e., the distribution of hydrocarbon flux between these reactions is determined by the ratio of the reaction rate constants and oxygen concentration near the surface.

10/00507 Deposition characteristics of diesel and bio-diesel fuels

Arifin, Y. M. and Arai, M. *Fuel*, 2009, 88, (11), 2163–2170.

The aim of this study is to investigate the deposition characteristics of different types of fuels by using the hot surface deposition test (HSDT) as a substitute procedure for real engine deposit tests. Deposit development, deposit compositions and deposit surface temperature fluctuation for diesel fuels and bio-diesel fuels (palm oil based and coconut oil based) are discussed. Deposit development depended on hot surface temperature, overlapping conditions, fuels, deposit properties, initial stage of deposition and competition phenomena during deposit formation. Results show DFP having 1% B100C in composition, showed a greater deposit development rate compared to DF, which resulted in a relatively large amount of deposits for DFP. However, for bio-diesel fuels, B100C obtained a slower deposit development rate compared to B100 although the test conditions were changed. Due to the lower value of MEP and shorter droplet lifetime before MEP, utilization of B100C had a greater potential in reducing deposit formation compared to B100.

10/00508 Effects of olefin on adsorptive desulfurization of gasoline over Ce(IV)Y zeolites

Wang, H. *et al. Fuel Processing Technology*, 2009, 90, (6), 835–838.

Effects of olefin on adsorptive deep desulfurization of gasoline over Ce(IV)Y zeolites have been studied via a FT-IR spectrometry and a fixed-bed adsorption technique at room temperature and atmosphere pressure by using model fuels containing thiophene and 1-octene as model compounds. The adsorptive selectivity for thiophene decreases significantly as the concentration of 1-octene increases. The difference in the FT-IR spectra between the Ce(IV)Y zeolite samples adsorbing the model fuels with and without 1-octene can be attributed to the stronger adsorption interactions of 1-octene with the Ce(IV)Y zeolite than those for thiophene. For minor content (500 μg/g) of thiophene and 1-octene, the FT-IR spectra show that the Ce(IV)Y zeolites have the preference to adsorb thiophene rather than 1-octene. However with the content of 1-octene increasing in the model fuel up to 150 mg/g, 1-octene can be adsorbed on the Ce(IV)Y zeolites remarkably, resulting in a descending adsorptive selectivity of the Ce(IV)Y for removing thiophene from the model fuel.

10/00509 Experimental investigation of burning rates of pure ethanol and ethanol blended fuels

Parag, S. and Raghavan, V. *Combustion and Flame*, 2009, 156, (5), 997–1005.

A fundamental experimental study to determine the burning rates of ethanol and ethanol-blended fossil fuels is presented. Pure liquid ethanol or its blends with liquid fossil fuels such as gasoline or diesel, has been transpired to the surface a porous sphere using an infusion pump. Burning of the fuel takes place on the surface of the porous sphere, which is placed in an air stream blowing upwards with a uniform velocity at atmospheric pressure and temperature under normal gravity conditions. At low air velocities, when ignited, a flame envelopes the sphere. For each sphere size, air stream velocity and fuel type, the fuel feed rate will vary and the same is recorded as the burning rate for that configuration. The flame stand-off distances from the sphere surface are measured by post-processing the digital image of the flame photograph using suitable imaging software. The transition velocity at which the flame moves and establishes itself at the wake region of the sphere has been determined for different diameters and fuel types. Correlations of these parameters are also presented.

10/00510 The viscosity of diesel oil and mixtures with straight vegetable oils: palm, cabbage palm, cotton, groundnut, copra and sunflower

Abollé, A. *et al. Biomass and Bioenergy*, 2009, 33, (9), 1116–1121.

The feedback experience of using straight vegetable oil (SVO) as a fuel in the existing diesel engines evidences the need for fitting several physical properties, among them the fuel viscosity. An empirical modelling is proposed in order to interpolate viscosity to any kind of diesel oil/SVO blend. This model is fitted on an experimental viscosity database on blends, varying the SVO mass proportion in the blend, the blend temperature between cloud point and 353 K, and including six vegetable oils varying the fatty acids composition. Extrusion rheology was also checked by varying the pressure drop. Measurements show that blends behave in a newtonian manner.

Transport, refining, quality, storage

10/00511 Deep desulphurization of diesel fuels on bifunctional monolithic nanostructured Pt-zeolite catalysts

Ismagilov, Z. R. *et al. Catalysis Today*, 2009, 144, (3–4), 235–250.

The preparation of Pt-zeolite catalysts, including choice of the noble metal precursor and loading (1.0–1.8 wt.%), was optimized for maximizing the catalytic activity in thiophene hydrodesulfurization (HDS) and benzene hydrogenation (HYD). According to data obtained by HRTEM, XPS, EXAFS and FTIR spectroscopy of adsorbed CO, the catalysts contained finely dispersed Pt nanoparticles (2–5 nm) located on montmorillonite and zeolite surfaces as: Pt^0 (main, $\nu_{CO} = 2070–2095\,cm^{-1}$), $Pt^{\delta+}$ ($\nu_{CO} = 2128\,cm^{-1}$) and $Pt^{2plus;}$ ($\nu_{CO} = 2149–2155\,cm^{-1}$). It was shown that the state of Pt depended on the Si/Al zeolite ratio, montmorillonite presence and Pt precursor. The use of H_2PtCl_6 as the precursor (impregnation) promoted stabilization of an oxidized Pt state, most likely $Pt(OH)_xCl_y$. When $Pt(NH_3)_4Cl_2$ (ion-exchange) was used, the Pt^0 and hydroxo- or oxy-complexes ${Pt(OH)_6}^{2-}$ or PtO_2 were formed. The addition of the Ca-montmorillonite favoured stabilization of $Pt^{+\delta}$. The Cl^- ions inhibit reduction of oxidized Pt state to Pt particles. The Pt-zeolite catalyst demonstrated high efficiency in ultra-deep desulfurization of DLCO. The good catalyst performance in hydrogenation activity and sulfur resistance can be explained by the favourable pore space architecture and the location and the state of the Pt clusters. The bimodal texture of the developed zeolite substrates allows realizing a concept for design of sulfur-resistant noble metal hydrotreating catalyst proposed in an earlier study.

10/00512 Effect of demineralization of El-lajjun Jordanian oil shale on oil yield

Al-Harahsheh, A. *et al. Fuel Processing Technology*, 2009, 90, (6), 818–824.

The effect of demineralization on oil yield and mineral composition of Jordanian oil shale was investigated. A standard digestion procedure using a range of inorganic and organic acids including HCl, HNO_3, HF, and CH_3COOH was used to enhance the oil recovery of oil shale samples collected from the El-lajjun area. The total yield of the digested samples, as determined by Fischer assay, has shown a maximum value (two folds the untreated sample) obtained when using CH_3COOH. The kaolin in the treated oil shale with a high concentration of CH_3COOH is believed to have transformed to illite as found in the XRD analysis. The treatment of oil shale using HCl has shown an increased ratio of oil to gas as a result of the digestion of calcite in the oil shale. At higher concentrations of HNO_3, the acid is believed to react with the kerogen in the oil shale resulting in high levels of low molecular weight compounds. Therefore, the amount of non-condensable gases produced by Fischer assay after treatment with a high concentration of HNO_3 is relatively high. HF is believed to drive off water from the oil shale by dissolving the clay minerals leading to increased oil to gas ratio.

10/00513 Energy-efficient ultra-deep desulfurization of kerosene based on selective photooxidation and adsorption

Tao, H. *et al. Fuel*, 2009, 88, (10), 1961–1969.

Selective photooxidation and adsorptive desulfurization of kerosene was investigated for fuel cell applications. Photooxidation was conducted using a 5 W low-pressure mercury lamp at 25 °C in the presence of O_2. It was found for the first time that the rates of photooxidation of dominant sulfur compounds remaining in commercial kerosene after hydrogenation were at least 100 times higher than those of benzothiophenes (BTs) and dibenzothiophenes (DBTs), although their molecular forms were not clarified. The photooxidation of these highly reactive sulfur compounds was completed within 30 min and made them removable by adsorbents such as molecular sieves. On the other hand, non-reactive sulfur compounds such as DBTs were removed by adsorbents such as activated carbon. Using this proposed method, which combines selective photooxidation of highly reactive sulfur compounds and adsorptive desulfurization of reactive and non-reactive sulfur compounds, the total sulfur content in kerosene can be efficiently reduced to less than $0.1\,\mu g\,g^{-1}$ (ppm) under mild conditions.

10/00514 Hydrogenated monoterpenes as diesel fuel additives

Tracy, N. I. *et al. Fuel*, 2009, 88, (11), 2238–2240.

Myrcene and limonene were hydrogenated to their fully saturated forms, 2,6-dimethyloctane and 1-isopropyl-4-methylcyclohexane, respectively. Mixtures of diesel fuel and up to 10% of each saturated hydrocarbon were tested by ASTM D975 to evaluate the 2,6-dimethyloctane and 1-isopropyl-4-methylcyclohexane as diesel fuel additives. The results showed that all tested mixtures were within the acceptable ranges specified by ASTM for diesel fuel and that the additives lowered the measured cloud point, compared to the base diesel fuel. Saturated limonene had positive effects on viscosity, as well. As myrcene and limonene are produced naturally in plants, these species represent a renewable route to fuel additives.

10/00515 Oil supply in Central and South America

Aguilera, R. F. *Energy Policy*, 2009, 37, (8), 2916–2925.

This paper estimates a cumulative supply curve for conventional oil in the Central and South American (CSA) region. The curve includes volumes from provinces not previously assessed by other organizations, as well as reserve growth. Volumes for the previously unassessed provinces are estimated using a variable shape distribution (VSD) model. Then the volumes are allocated to CSA countries based on each country's share of proved reserves. Figures provided by the cumulative supply curve are stock variables for all time, unlike the traditional supply curve where they are flow variables that can continue from one period to the next. In this study, the fixed stock approach is used since it provides practical information with respect to the concerns that some have expressed about oil scarcity in the near future. Results indicate that Central and South American oil is more abundant than often assumed, and can be produced at costs below current market oil prices, and substantially below mid-2008 prices.

10/00516 Oxidative desulphurization of light cycle oil: monitoring by FTIR spectroscopy

Toteva, V. *et al. Fuel Processing Technology*, 2009, 90, (7–8), 965–970.

Oxidative desulfurization has received attention as an alternative or an additional technology for deep fuel desulfurization. The authors studied oxidative desulfurization as an approach to remove sulfur organic compounds in light cycle oil. By FTIR spectroscopy appropriate conditions for oxidation have been experimentally identified as up to 90% of the sulfur compounds in LCO were removed. This spectroscopic technique allowed sulfones quantification by $1302\,cm^{-1}$ band interpretation. In as much as sulfones have higher polarity than the parent sulfide molecules, they are preferentially extracted from the feedstock. FTIR analysis permits to estimate degree of the sulfur compounds oxidation, degree of desulfurization by extraction method and to register micro quantity of oxidized products.

10/00517 Recent advances in sulfur removal from gasoline by pervaporation

Lin, L. *et al. Fuel*, 2009, 88, (10), 1799–1809.

Pervaporation (PV) is today considered as a promising unit operation for separation of organic–organic liquid mixtures and is being investigated extensively in chemical and petrochemical industries. Recently, PV applications in environment cleanup operations, especially in the removal of sulfur compounds from gasoline have attracted increasing attention worldwide. Gasoline desulfurization by PV is a newly emerged technology in which sulfur components can be preferentially removed from the gasoline feed due to its higher affinity with, and/or quicker diffusivity in the membrane. A considerable amount of background information, current state and trends of the new PV application in gasoline desulfurization are dealt with. The article focuses on the PV membranes development, interactions between gasoline components and membranes, the improvement in process engineering, techoeconomical analysis and the technology scale up. Finally, some suggestions for further research were presented with the aim of reducing the cost in introducing the PV process into refineries for desulfurization.

10/00518 Removal of fine particles in wet flue gas desulfurization system by heterogeneous condensation

Yang, L. *et al. Chemical Engineering Journal*, 2009, 156, (1), 25–32.

A novel process to remove fine particles with high efficiency by heterogeneous condensation in a wet flue gas desulfurization (WFGD) system is presented. A supersaturated vapour phase, necessary for condensational growth of fine particles, was achieved in the SO_2 absorption zone and at the top of the wet FGD scrubber by adding steam in the gas inlet and above the scrubbing liquid inlet of the scrubber, respectively. The condensational grown droplets were then removed by the scrubbing liquid and a high-efficiency demister. The results show that the effectiveness of the WFGD system for removal of fine particles is related to the SO_2 absorbent employed. When using $CaCO_3$ and $NH_3 \cdot H_2O$ to remove SO_2 from flue gas, the fine particle removal efficiencies are lower than those for Na_2CO_3 and water, and the morphology and elemental composition of fine particles are changed. This effect can be attributed to the formation of aerosol particles in the limestone and ammonia-based FGD processes. The performance of the WFGD system for removal of fine particles can be significantly improved for both steam addition cases, for which the removal efficiency increases with increasing amount of added steam. A high liquid to gas ratio is beneficial for efficient removal of fine particles by heterogeneous condensation of water vapour.

10/00519 Resistance properties of coal–water slurry flowing through local piping fittings

Liu, M. and Duan, Y. F. *Experimental Thermal and Fluid Science*, 2009, 33, (5), 828–837.

Local resistance characteristics of coal–water slurry (CWS) flowing through three types of piping components, namely gradual contractions, sudden contractions and 90° horizontal bends, were investigated at a transportation test facility. The results show that CWS exhibits different rheological behaviours, i.e. the shear-thinning, newtonian, and shear-thicken, at different shear rates. When CWS flows through the gradual contractions, the local pressure loss firstly decreases to a minimum, and then increases as the gradual contraction angle (θ) increases. When the CWS flow through the sudden contractions, with the increase of pipe diameter ratio (β), the local pressure loss increases for the two kinds of CWS, SHEN-HUA (S-H) CWS and YAN-ZHOU (Y-Z) CWS whose mass concentration range from 57% to 59% and 59% to 62%, respectively. For 90° horizontal bends, there is an optimal value of the bend diameter ratio (Rc/D) at which the local pressure loss is the least. Furthermore, the local resistance coefficient (K) in the empirical correlations is determined from the experimental data. The correlations show that as Re increases, K of the three fittings declines quickly at first. However, with further increase in Re, K shows different behaviours for the three fittings due to the special rheological property of CWS at higher shear rates. The factors of θ, β and Rc/D have minor effects on K.

10/00520 Studies of the effect of retorting factors on the yield of shale oil for a new comprehensive utilization technology of oil shale

Han, X. X. *et al. Applied Energy*, 2009, 86, (11), 2381–2385.

The comprehensive utilization of oil shale is a new promising technology achieving high utilization-factors for both oil shale's chemical and energy potentials, and avoiding serious environmental impacts. For this technology, it is an urgent issue how to obtain shale oil with a high yield and as well as treat shale char efficiently and economically. In this present work, retorting experiments of three type I oil shales were performed using an aluminium retort, and the effect of retorting temperature, residence time, particle size and heating rate on the yield of shale oil was studied at low retorting temperatures ranging from 400 °C to 520 °C, respectively, at which shale char obtained has good combustion properties. The experimental data show that an increase in the retorting temperature, the residence time and the heating time has positive significant effect on improving the yield of shale oil, and a middle particle size is helpful for increasing the oil yield as well. The grey system method was applied to evaluate the effect of retorting factors on the yield of shale oil, showing that the retorting temperature is the most marked factor influencing the yield of shale oil.

10/00521 The impact of ethanol production on US and regional gasoline markets

Du, X. and Hayes, D. J. *Energy Policy*, 2009, 37, (8), 3227–3234.

This study quantifies the impact of increasing ethanol production on wholesale/retail gasoline prices employing pooled regional time-series data from January 1995 to March 2008. The growth in ethanol production has kept wholesale gasoline prices $0.14/gallon lower than would otherwise have been the case. The negative impact of ethanol on retail gasoline prices is found to vary considerably across regions. The Midwest region has the biggest impact at $0.28/gallon, while the Rocky Mountain region had the smallest impact at $0.07/gallon. The results also indicate that the ethanol-induced reduction in gasoline prices comes at the expense of refiners' profits. A net welfare loss of $0.5 billion was found from the ethanol support policies in multiple markets.

10/00522 The Trans-Caspian energy route: cronyism, competition and cooperation in Kazakh oil export

Guliyev, F. and Akhrarkhodjaeva, N. *Energy Policy*, 2009, 37, (8), 3171–3182.

The article delineates the major national, regional and international level stakeholders in the westward Trans-Caspian transportation of Kazakh oil, supplemented with a discussion of the prospect of expansion of the Trans-Caspian/South Caucasus corridor in light of the presumably harmful effect of the war between Russia and Georgia in August 2008. It demonstrates that while foreign companies have been backed by their respective governments, national firms have also enjoyed considerable state support, partly due to their close links to the interests of state elites in Kazakhstan and Azerbaijan. It appears that most companies along the shipping line either belong to the governments of Kazakhstan or Azerbaijan, directly or indirectly (through subsidiaries), or enjoy favouritism and a near monopoly in their markets (crony capitalism). Some of these firms are privately owned but registered in offshore tax havens, while some others have rather obscure ownership structures and corporate profiles. It suggests that cronyism and state capture comprise that politico-economic environment within which the future of Caspian transport systems will have to be decided.

10/00523 Upgrading of liquid fuel from the vacuum pyrolysis of biomass over the Mo–Ni/γ-Al_2O_3 catalysts

Xu, Y. *et al. Biomass and Bioenergy*, 2009, 33, (8), 1030–1036.

High amounts of acid compounds in bio-oil not only lead to the deleterious properties such as corrosiveness and high acidity, but also set up many obstacles to its wide applications. By hydrotreating the bio-oil under mild conditions, some carboxylic acid compounds could be converted to alcohols which would esterify with the unconverted acids in the bio-oil to produce esters. The properties of the bio-oil could be improved by this method. In the paper, the raw bio-oil was produced by vacuum pyrolysis of pine sawdust. The optimal production conditions were investigated. A series of nickel-based catalysts were prepared. Their catalytic activities were evaluated by upgrading of model compound (glacial acetic acid). Results showed that the reduced Mo–10Ni/γ-Al_2O_3 catalyst had the highest activity with the acetic acid conversion of 33.2%. Upgrading of the raw bio-oil was investigated over reduced Mo–10Ni/γ-Al_2O_3 catalyst. After the upgrading process, the pH value of the bio-oil increased from 2.16 to 2.84. The water content increased from 46.2 wt.% to 58.99 wt.%. The H element content in the bio-oil increased from 6.61 wt.% to 6.93 wt.%. The dynamic viscosity decreased a little. The results of GC–MS spectrometry analysis showed that the ester compounds in the upgraded bio-oil increased by three times. It is possible to improve the properties of bio-oil by hydrotreating and esterifying carboxyl group compounds in the bio-oil.

Economics, business, marketing, policy

10/00524 Carbon dioxide *versus* energy balances for transportation fuels

Pritchard, H. O. *Energy & Environment Science*, 2009, 2, (2), 815–817.

This paper provides tables of energy content per litre and of CO_2 production per unit energy for a representative selection of molecules, as an aid to quantifying the advantages, or otherwise, of using ethanol and/or butanol as transportation fuels.

10/00525 Does ownership matter? The performance and efficiency of State Oil vs. Private Oil (1987–2006)

Wolf, C. *Energy Policy*, 2009, 37, (7), 2642–2652.

This paper investigates the existence of ownership effects in the global oil and gas industry, i.e. whether there are systematic performance and efficiency differentials between national oil companies (NOCs) and privately owned international oil companies (IOCs). After discussing key issues of comparing 'state oil' and 'private oil', the author summarizes important trends emerging from the dataset, which covers 1001 firm observation years over the period 1987–2006. Using panel-data regression analysis it is shown that NOCs significantly underperform the private sector in terms of output efficiency and profitability. They also produce a significantly lower annual percentage of upstream reserves, although this may not be an indication of firm efficiency. Overall, this paper suggests that a political preference for state oil usually comes at an economic cost.

10/00526 Estimating the impact of extreme events on crude oil price: an EMD-based event analysis method

Zhang, X. *et al. Energy Economics*, 2009, 31, (5), 768–778.

The impact of extreme events on crude oil markets is of great importance in crude oil price analysis due to the fact that those events generally exert strong impact on crude oil markets. For better estimation of the impact of events on crude oil price volatility, this study attempts to use an EMD-based event analysis approach for this task. In the proposed method, the time series to be analysed is first decomposed into several intrinsic modes with different time scales from fine-to-coarse and an average trend. The decomposed modes respectively capture the fluctuations caused by the extreme event or other factors during the analysed period. It is found that the total impact of an extreme event is included in only one or several dominant modes, but the secondary modes provide valuable information on subsequent factors. For overlapping events with influences lasting for different periods, their impacts are separated and located in different modes. For illustration and verification purposes, two extreme events, the Persian Gulf War in 1991 and the Iraq War in 2003, are analysed step by step. The empirical results reveal that the EMD-based event analysis method provides a feasible solution to estimating the impact of extreme events on crude oil prices variation.

10/00527 Long memory in US disaggregated petroleum consumption: evidence from univariate and multivariate LM tests for fractional integration

Lean, H. H. and Smyth, R. *Energy Policy*, 2009, 37, (8), 3205–3211.

Previous studies that have tested for a unit root in aggregate energy consumption have potentially reached misleading conclusions because they fail to allow for the possibility that energy consumption might be fractionally integrated and do not distinguish between different types of energy consumption. This study tests for long memory in disaggregated petroleum consumption in the USA using univariate and multivariate Lagrange multiplier (LM) tests for fractional integration. The results point strongly to the need to distinguish between different forms of energy consumption and allow for a generalization of the $I(0)/I(1)$ dichotomy when considering the order of integration of energy consumption. Allowing for short-run dynamics, the univariate test suggests that less than 50% of the series are fractionally integrated. Consistent with expectations the non-stationary series are found to have the highest mean and standard deviation. The multivariate test suggests that petroleum consumption in the commercial and industrial sectors is clearly fractionally integrated when allowing for short-run dynamics, and, as such, exhibits persistent effects, while petroleum consumption in the residential sector is a stationary process.

10/00528 OPEC plans more condensate production

Anon., *Oil and Energy Trends*, 2009, 34, (10), 3–6.

OPEC's natural gas liquid (NGL) production is planned to increase in response to market demand. NGL is not subject to the production controls that apply to crude oil, which makes it a popular product, however it can in some circumstances compete directly with crude oil and even depress the export price of crude oil.

10/00529 Regime-switching stochastic volatility: evidence from the crude oil market

Vo, M. T. *Energy Economics*, 2009, 31, (5), 779–788.

This paper incorporates regime switching into the stochastic volatility (SV) framework in an attempt to explain the behaviour of crude oil prices in order to forecast their volatility. More specifically, it models the volatility of oil return as a stochastic volatility process whose mean is subject to shifts in regime. The shift is governed by a two-state first-order Markov process. The Bayesian Markov Chain Monte Carlo method is used to estimate the models. The main findings are: first, there is clear evidence of regime switching in the oil market. Ignoring it will lead to a false impression that the volatility is highly persistent and therefore highly predictable. Second, incorporating regime switching into the SV framework significantly enhances the forecasting power of the SV model. Third, the regime switching stochastic volatility model does a good job in capturing major events affecting the oil market.

10/00530 The effects of crude oil shocks on stock market shifts behaviour: a regime switching approach

Aloui, C. and Jammazi, R. *Energy Economics*, 2009, 31, (5), 789–799.

This study develops a two-regime Markov-switching EGARCH model introduced by Henry, to examine the relationship between crude oil shocks and stock markets. An application to stock markets of UK, France and Japan over the sample period January 1989 to December 2007 illustrates plausible results. The authors detect two episodes of series behaviour, one relative to low mean/high variance regime and the other to high mean/low variance regime. Furthermore, there is evidence that common recessions coincide with the low mean/high variance regime. In addition, the authors allow both real stock returns and probability of transitions from one regime to another to depend on the net oil price increase variable. The findings show that rises in oil price has a significant role in determining both the volatility of stock returns and the probability of transition across regimes.

10/00531 The macroeconomic effects of oil price fluctuations on a small open oil-producing country: the case of Trinidad and Tobago

Lorde, T. *et al. Energy Policy*, 2009, 37, (7), 2708–2716.

Using vector autoregressive (VAR) methodology, this paper empirically investigates the macroeconomic effects of oil price fluctuations on Trinidad and Tobago. Overall, the price of oil was found to be is a major determinant of economic activity of the country. The impulse response functions suggest that following a positive oil price shock, output falls within the first two years followed by positive and growing response. Investigate the macroeconomic impact of oil price volatility suggested that an unanticipated shock to oil price volatility brings about random swings in the macroeconomy; however, only government revenue and the price level exhibit significant responses. With regard to the magnitude of the responses, shocks to oil price volatility tend to yield smaller macroeconomic impacts in comparison to shocks to oil prices. Variance decompositions suggest that the price of oil is a major component of forecast variation for most macroeconomic variables. Finally, Granger-causality tests indicate causality from oil prices to output and oil prices to government revenue.

Derived liquid fuels

10/00532 A comparative study of combination of Fischer–Tropsch synthesis reactors with hydrogen-permselective membrane in GTL technology

Rahimpour, M. R. and Elekaei, H. *Fuel Processing Technology*, 2009, 90, (6), 747–761.

This work proposes a one-dimensional heterogeneous model to analyse the performance of combination of Fischer–Tropsch synthesis (FTS) reactors in which a fixed-bed reactor is combined with a membrane assisted fluidized-bed reactor. This model is used to compare the performance of the proposed system with a fixed-bed single stage reactor. In the new concept, the synthesis gas is converted to FT products in two catalytic reactors. The first reactor is water-cooled fixed-bed type while the second reactor is gas-cooled and fluidized-bed. Due to the decrease of H_2/CO to values far from optimum reactants ratio, the membrane concept is suggested to control hydrogen addition. Moreover, a fluidized-bed system has been proposed to solve some observed drawbacks of industrial fixed-bed reactors such as high pressure drop, heat transfer problem and internal mass transfer limitations. This novel concept, named a fluidized-bed membrane dual-type reactor, is used for production of gasoline from synthesis gas. The reactor model is tested against the pilot plant data of the Research Institute of Petroleum Industry. Results show an enhancement in the gasoline yield, a main decrease in CO_2 formation and a favourable temperature profile along the proposed concept.

10/00533 Fischer-Tropsch synthesis: relations between structure of cobalt catalysts and their catalytic performance

Khodakov, A. Y. *Catalysis Today*, 2009, 144, (3–4), 251–257.

Fischer–Tropsch synthesis has been experiencing a strong revival in recent years, due to the resource utilization considerations and environmental concerns. Cobalt supported catalysts represent the optimal choice for the synthesis of long-chained hydrocarbons from syngas with high H_2/CO ratio. This paper reviews the state of the art related to the influence of cobalt particle size and cobalt phase composition, catalyst support and support texture, and promotion with noble metals on Fischer–Tropsch reaction rates, hydrocarbon selectivity and catalyst stability. Possible mechanisms of catalyst deactivation and modification of cobalt active sites during the reaction are also discussed. Several requirements to the design of cobalt Fischer–Tropsch catalysts have been specified.

10/00534 Influence of sewage sludge on the slurryability of coal–water slurry

Li, W. *et al. Fuel*, 2009, 88, (11), 2241–2246.

In this study, the maximum solids loading, stability and rheological properties of coal–sludge slurries were investigated and compared with those of coal–water slurries. The maximum solids content of coal–sludge slurry was much lower than that of coal–water slurry because of the 82% water in sewage sludge. NaOH addition as a pre-treatment of sewage sludge improved the maximum solids content to 61% and 60% for dispersants A_1 and A_2, respectively, for a sludge–coal mass ratio of 22.1:100. Compared to coal–water slurries, the stability of coal–sludge slurries was better, with no solid deposition after 96 h. Coal particles and sewage sludge formed a stable medium and settlement of large coal particles was prevented. All the coal–sludge slurries exhibited pseudo-plastic behaviour; this type of fluid is shear-thinning and is easy to transport.

10/00535 Molecular analysis of petroleum derived compounds that adsorb onto gas hydrate surfaces

Borgund, A. E. *et al. Applied Geochemistry*, 2009, 24, (5), 777–786.

Field observations have shown that some streams of water, gas and crude oil do not form gas hydrate plugs during petroleum production even when operating within thermodynamic conditions for hydrate formation. Also, when studied under controlled laboratory conditions, some oils are found to form hydrate dispersed systems whereas others form plugs. Oils with low tendency to form hydrate plugs are believed to contain natural hydrate plug inhibiting components (NICs) that adsorb onto the hydrate surface, making them less water-wet and preventing the particles from agglomerating into large hydrate clusters. The molecular structure of the NICs is currently unknown. In this work, hydrate adsorbing components were extracted from crude oils using freon hydrates as an extraction phase. The fractions were found to be enriched in polar material, and more polar material is associated with hydrates generated in biodegraded crude oils than in non-biodegraded oils. Various fractionation schemes and analytical techniques have been applied in the search for molecular characterization. The average molecular weights were found to be approximately 500 g/mole. GC–MS chromatograms show a large UCM (Unresolved Complex Mixture). Thus, GC–MS has a limited potential for identification of compounds. A commercial biosurfactant was used as a model compound in the search for similar structures in the extracts. The results from analysis of the hydrate adsorbing components suggest that the type and structure are more important for hydrate morphology than the amount of material adsorbed.

10/00536 Phosphorus induced hydrothermal stability and enhanced catalytic activity of ZSM-5 in methanol to DME conversion

Lee, Y.-J. *et al. Fuel*, 2009, 88, (10), 1915–1921.

The change in properties of ZSM-5 samples was achieved by treatment with phosphorus compounds (trimethyl phosphite or phosphoric acid) and the resultant materials were characterized by N_2 adsorption, NH_3-TPD, ^{27}Al, and ^{31}P MAS NMR techniques. The phosphorus-treated HZSM-5 (P/ZSM-5) samples exhibited lower acidity, higher hydrothermal stability and improved dimethyl ether (DME) selectivity in methanol conversion when compared to the phosphorus-free HZSM-5. ^{27}Al, and ^{31}P MAS NMR results revealed that the added P indeed interacted with the ZSM-5 framework and is responsible for the changes observed in the catalytic properties. The interaction caused the decrease in strong acid sites on one hand and creation of new acid sites (NH_3-TPD) on the other, in P/ZSM-5 samples. The studies indicated the need of optimizing the P loading, where the positive role of P on the catalytic activity was observed to be maximum at P/Al molar ratio of 1.05.

10/00537 Production of FAME by palm oil transesterification via supercritical methanol technology

Tan, K. T. *et al. Biomass and Bioenergy*, 2009, 33, (8), 1096–1099.

The present study employed non-catalytic supercritical methanol technology to produce biodiesel from palm oil. The research was carried out in a batch-type tube reactor and heated beyond supercritical temperature and pressure of methanol, which are at 239 °C and 8.1 MPa respectively. The effects of temperature, reaction time and molar ratio of methanol to palm oil on the yield of fatty acid methyl esters (FAME) or biodiesel were investigated. The results obtained showed that non-catalytic supercritical methanol technology only required a mere 20 min reaction time to produce more than 70% yield of FAME. Compared to conventional catalytic methods, which required at least 1 h reaction time to obtain similar yield, supercritical methanol technology has been shown to be superior in terms of time and energy consumption. Apart from the shorter reaction time, it was found that separation and purification of the products were simpler since no catalyst is involved in the process. Hence, formation of side products such as soap in catalytic reactions does not occur in the supercritical methanol method.

03 GASEOUS FUELS

Sources, properties, recovery, treatment

10/00538 Evaluation of gas content of coalbed methane reservoirs with the aid of geophysical logging technology

Fu, X. *et al. Fuel*, 2009, 88, (11), 2269–2277.

The geophysical logging technology has been employed in connection with field and laboratory tests for coal reservoir evaluation in Huainan and Huaibei coalfields, China. The relationships between coalbed gas content of coal reservoir and characteristics of geophysical logs have been investigated by means of the combined analyses of experimental and geophysical logging data. Coalbed gas content of drilling core samples from coal seams was determined experimentally. The results, together with the log data obtained from geophysical logging technology, have been analysed by using geological statistics, permitting correlation of the coalbed gas content to the log responses. The correlation developed in this study provides better understanding of the coal reservoir for coalbed methane exploration in given coalfields by an improved prediction of the coalbed gas content.

10/00539 Prediction of hydrate formation temperature by both statistical models and artificial neural network approaches

Zahedi, G. *et al. Energy Conversion and Management*, 2009, 50, (8), 2052–2059.

In this study, various estimation methods have been reviewed for hydrate formation temperature (HFT) and two procedures have been presented. In the first method, two general correlations have been proposed for HFT. One of the correlations has 11 parameters, and the second one has 18 parameters. In order to obtain constants in proposed equations, 203 experimental data points have been collected from literatures. The Engineering Equation Solver (EES) and Statistical Package for the Social Sciences (SPSS) software programs have been employed for statistical analysis of the data. Accuracy of the obtained correlations also has been declared by comparison with experimental data and some recent common used correlations. In the second method, HFT is estimated by artificial neural network (ANN) approach. In this case, various architectures have been checked using 70% of experimental data for training of ANN. Among the various architectures multi-layer perceptron (MLP) network with trainlm training algorithm was found as the best architecture. Comparing the obtained ANN model results with 30% of unseen data confirms ANN excellent estimation performance. It was found that ANN is more accurate than traditional methods and even the two proposed correlations for HFT estimation.

10/00540 The chemical origin of octane sensitivity in gasoline fuels containing nitroalkanes

Cracknell, R. F. *et al. Combustion and Flame*, 2009, 156, (5), 1046–1052.

Experimental octane measurements are presented for a standard gasoline to which has been added various quantities of nitromethane, nitroethane and 1-nitropropane. The addition of nitroalkanes was found to suppress the Motor Octane Number to a much greater extent than the Research Octane Number. In other words addition of nitroalkanes increases the octane sensitivity of gasoline. Density functional theory was used to model the equilibrium thermodynamics and the barrier heights for reactions leading to the break-up of nitroethane. These results were used to develop a chemical kinetic scheme for nitroalkanes combined with a surrogate gasoline (for which a mechanism has been developed previously). Finally the chemical kinetic simulations were combined with a quasi-dimensional engine model in order to predict autoignition in octane rating tests. These results suggest that the chemical origin of octane sensitivity in gasoline/nitroalkane blends cannot be fully explained on the conventional basis of the extent to which NTC behaviour is absent. Instead the authors have shown that the contribution of the two pathways leading to autoignition in gasoline containing nitroalkanes becomes much more significant under the more severe conditions of the Motor Octane method than the Research Octane method.

10/00541 Visible emission of hydrogen flames

Schefer, R. W. *et al. Combustion and Flame*, 2009, 156, (6), 1234–1241.

The common misconception that hydrogen flames are not visible is examined. Examples are presented of clearly visible emissions from typical hydrogen flames. It is shown that while visible emissions from these flames are considerably weaker than those from comparable hydrocarbon flames, they are indeed visible, albeit at reduced light levels in most cases. Detailed flame spectra are presented to characterize flame emission bands in the ultraviolet, visible and infrared regions of the spectrum that result in a visible hydrogen flame. The visible blue emission is emphasized, and recorded spectra indicate that fine spectral structure is superimposed on a broadband continuum extending from the ultraviolet into the visible region. Tests were performed to show that this emission does not arise from carbon or nitrogen chemistry resulting from carbon-containing impurities (hydrocarbons) in the hydrogen fuel or from CO_2 or N_2 entrainment from the surrounding air. The spectral structure, however, is also observed in methane flames. The magnitude of the broadband emission increases with flame temperature in a highly non-linear manner while the finer spectral structure is insensitive to temperature. A comparison of diffusion and premixed H_2 flames shows that the fine scale structure is comparable in both flames.

Transport, storage

10/00542 Analysis of biogas compression system dynamics

Morini, M. *et al. Applied Energy*, 2009, 86, (11), 2466–2475.

The use of biogas for energy production has progressively increased in recent years, due to an increasing interest both in agricultural and energy policies of many industrialized countries. Biogas compression by means of natural gas infrastructure seems the most immediate solution, but could also lead to problems due to the different physical properties of the two gases. In this paper, a non-linear one-dimensional modular dynamic model is developed and used for the simulation of compression system transient behaviour. The arrangement consists of a main line, where the compressor operates, and an anti-surge control, which consists of a recycle loop activated by a fast acting valve. Different manoeuvres (start-up, normal operation, emergency shut-down and operating point variation) are simulated by using two different working fluids (methane and biogas). Simulations prove that the design of the surge protection system should consider the fluid to be elaborated. Moreover, system predisposition to surge increases as the ratio between system volumes and the inertia of the rotating masses increases.

10/00543 Dissolution of Columbia River Basalt under mildly acidic conditions as a function of temperature: experimental results relevant to the geological sequestration of carbon dioxide

Schaef, H. T. and McGrail, B. P. *Applied Geochemistry*, 2009, 24, (5), 980–987.

Increasing attention is being focused on the rapid rise of CO_2 levels in the atmosphere, which many believe to be the major contributing factor to global climate change. Sequestering CO_2 in deep geological formations has been proposed as a long-term solution to help stabilize CO_2 levels. However, before such technology can be developed and implemented, a basic understanding of H_2O–CO_2 systems and the chemical interactions of these fluids with the host formation must be obtained. Important issues concerning mineral stability, reaction rates, and carbonate formation are all controlled or at least significantly impacted by the kinetics of rock–water reactions in mildly acidic, CO_2-saturated solutions. Basalt has recently been identified as a potentially important host formation for geological sequestration. Dissolution kinetics of the Columbia River Basalt (CRB) were measured for a range of temperatures (25–90 °C) under mildly acidic to neutral pH conditions using the single-pass flow-through test method. Under anaerobic conditions, the normalized dissolution rates for CRB decrease with increasing pH ($3 \leq \mathrm{pH} \leq 7$) with a slope, η, of -0.15 ± 0.01. Activation energy, E_a, has been estimated at $32.0 \pm 2.4\,\mathrm{kJ\,mol^{-1}}$. Dissolution kinetics measurements like these are essential for modelling the rate at which CO_2-saturated fluids react with basalt and ultimately drive conversion rates to carbonate minerals *in situ*.

10/00544 Integrating a full carbon capture scheme onto a $450\,\mathrm{MW_e}$ NGCC electric power generation hub for offshore operations: presenting the Sevan GTW concept

Hetland, J. *et al. Applied Energy*, 2009, 86, (11), 2298–2307.

Sevan Marine and Siemens have developed a floating power plant – entitled Sevan GTW (gas-to-wire) – based on Sevan's cylindrical platform and Siemens' SCC-800 combined cycle, and SINTEF has adapted a post-combustion CO_2 capture process for on-board integration including compression and preconditioning of the CO_2. The main emphasis has been placed on developing an optimized conceptual design within the structural constraints, and assessing how efficient the capture unit may be operated in consideration of the dynamic behaviour induced by the sea on the absorber and desorber columns via the floating carrier. The rational behind this technology selection is the urgency in making appropriate steps for a quick start for remote power generation at sea with the inclusion of CCS to serve offshore oil and gas operations. This calls for modular power blocks made up by high efficient combined power cycles with post-combustion exhaust gas cleaning. From this point of view a system with four absorption columns and one desorber unit has been determined based on structured packing material. The capture process has been integrated with the power cycle in due consideration of the sea forces. It is shown that a permanent tilt becomes more important than periodic movements provided the harmonic periods are kept within a certain level (<20 s). Operational conditions and constraints *vis-à-vis* movements and trimming of the floater have been addressed and discussed with reference to available literature. This also includes the liquid hold-up and gas–liquid interfacial area in the absorption columns linked with tilting. Optimization reveals that a reboiler duty of 3.77 GJ/ton CO_2 would result in the lowest capture cost. With a energy penalty of 9%-points the Sevan GTW concept presents itself as a realistic concept deemed to be within reach today.

10/00545 Performance analysis of a new tank configuration applied to the natural gas storage systems by adsorption

Santos, J. C. *et al. Applied Thermal Engineering*, 2009, 29, (11–12), 2365–2370.

This work presents a numerical study of a new tank configuration applied to natural gas storage systems by adsorption. The traditional tanks employed in natural gas storage by adsorption reveal serious limitations for use in fast charge systems because of their inefficiency in the dissipation of adsorption heat. In order to eliminate the detrimental effects of adsorption heat, and to make viable the fast charge of gas in automotive tanks, a vessel made up of several tubes, compacted with activated carbon, was proposed. In the charge process, the gas circulates through the tank and all non-adsorbed gasses pass through an external heat exchanger installed close to the gas source of the refueling station. The numerical results obtained in the present work showed that the charge time of the new system can vary from 50 to 200 s, depending on the applied mass flow rate. These time periods are considered satisfactory for fast charge conditions. Another advantage of this new system is that there will be no need to include the accessories employed in traditional tanks, such as: fins, perforated tube in the tank centre and a cooling external jacket, which would increase the complexity of the vessel design.

10/00546 Post combustion CO_2 capture by carbon fibre monolithic adsorbents

Thiruvenkatachari, R. *et al. Progress in Energy and Combustion Science*, 2009, 35, (5), 438–455.

As generation of carbon dioxide (CO_2) greenhouse gas is inherent in the combustion of fossil fuels, effective capture of CO_2 from industrial and commercial operations is viewed as an important strategy which has the potential to achieve a significant reduction in atmospheric CO_2 levels. At present, there are three basic capture methods, i.e. post combustion capture, pre-combustion capture and oxy-fuel combustion. In pre-combustion, the fossil fuel is reacted with air or oxygen and is partially oxidized to form CO and H_2. Then it is reacted with steam to produce a mixture of CO_2 and more H_2. The H_2 can be used as fuel and the carbon dioxide is removed before combustion takes place. Oxy-combustion is when oxygen is used for combustion instead of air, which results in a flue gas that consists mainly of pure CO_2 and is potentially suitable for storage. In post combustion capture, CO_2 is captured from the flue gas obtained after the combustion of fossil fuel. The post combustion capture (PCC) method eliminates the need for substantial modifications to existing combustion processes and facilities; hence, it provides a means for near-term CO_2 capture for new and existing stationary fossil fuel-fired power plants. This paper briefly reviews CO_2 capture methods, classifies existing and emerging post combustion CO_2 capture technologies and compares their features. The paper goes on to investigate relevant studies on carbon fibre composite adsorbents for CO_2 capture, and discusses fabrication parameters of the adsorbents and their CO_2 adsorption performance in detail. The paper then addresses possible future system configurations of this process for commercial applications. Finally, while there are many inherent attractive features of flow-through channelled carbon fibre monolithic adsorbents with very high CO_2 adsorption capabilities, further work is required for them to be fully evaluated for their potential for large scale CO_2 capture from fossil fuel-fired power stations.

Economics, business, marketing, policy

10/00547 Economic evaluation of natural gas transportation from Iran's South-Pars gas field to market

Najibi, H. *et al. Applied Thermal Engineering*, 2009, 29, (10), 2009–2015.

The worldwide consumption of natural gas is increasing rapidly. To satisfy such a demand, there are some plans to transport natural gas from South-Pars gas field, the largest natural gas field of Iran, to some energy consuming countries. There are several possible technologies for transporting gas from production fields to consuming markets as gas, including PNG (pipeline natural gas), LNG (liquefied natural gas), CNG (compressed natural gas) and NGH (natural gas hydrate). Gas transmission projects are sensitive to technology selection and depending on the capacity and distance; chosen technology may affect the economy of the entire project noticeably. In this work, transporting 100×10^6 standard m^3/d natural gas from port of Assaluyeh in south of Iran to potential markets using alternative technologies such as PNG, LNG, CNG and NGH has been investigated. To do such a study, required processes for converting natural gas to desired product and then transporting it to market have been designed and using an economical model, cost of transporting natural gas as a function of distance, has been estimated. Results show for the investigated case, PNG has the lowest production cost for distances up to 7600 km and for larger distances, LNG has the lowest production cost.

10/00548 EU seeks gas amid Iraqui confusion

Anon., *Oil and Energy Trends*, 2009, 34, (8), 3–6.

This article focuses on the European Union (EU) attempts to secure natural gas from Iraq for its Nabucco pipeline scheme. Foreign oil and gas companies have signed deals with Iraq to develop Iraqi gasfields and exports are being forecast within a few years. Cooperation with Kurdistan will be needed, however, as some of the gas lies within its borders.

10/00549 Natural gas requirement by fertilizer sector in India

Parikh, J. *et al. Energy*, 2009, 34, (8), 954–961.

Natural gas is one of the important fossil fuel energy resources in India. Anchor customers of natural gas are the power sector and nitrogenous fertilizer. It is the cleanest form of energy derived from the fossil fuel basket. Because of clean combustion characteristics, natural gas is the fuel choice for many sections of Indian industry. The demand for natural gas will grow with time. Currently natural gas accounts for 7% of the primary energy consumption of India. The government of India has its commitment to food security and energy security. The policies are directed toward greater allocation of natural gas on a priority basis to fertilizer and the power sector. Natural gas is the main and preferred feedstock for urea manufacture. This paper analyses and estimates projected demand of natural gas in the next two decades. The demand projections have been reviewed in the context of changing government policies regarding the fertilizer industry, such as farm gate price regulation and self-sufficiency level of indigenous urea production. The current growth plan of natural gas supply and evolving supply scenario in the future are also considered in the study.

10/00550 Preliminary report on the commercial viability of gas production from natural gas hydrates

Walsh, M. R. *et al. Energy Economics*, 2009, 31, (5), 815–823.

Economic studies on simulated gas hydrate reservoirs have been compiled to estimate the price of natural gas that may lead to economically viable production from the most promising gas hydrate accumulations. As a first estimate, $\text{CDN\$}_{2005}$ 12/Mscf is the lowest gas price that would allow economically viable production from gas hydrates in the absence of associated free gas, while an underlying gas deposit will reduce the viability price estimate to $\text{CDN\$}_{2005}$ 7.50/Mscf. Results from a recent analysis of the simulated production of natural gas from marine hydrate deposits are also considered in this report; on an IROR basis, it is $\text{US\$}_{2008}$ 3.50–4.00/Mscf more expensive to produce marine hydrates than conventional marine gas assuming the existence of sufficiently large marine hydrate accumulations. While these prices represent the best available estimates, the economic evaluation of a specific project is highly dependent on the producibility of the target zone, the amount of gas in place, the associated geologic and depositional environment, existing pipeline infrastructure, and local tariffs and taxes.

10/00551 Regulatory intervention on the dynamic European gas market – neoclassical economics or transaction cost economics?

Spanjer, A. R. *Energy Policy*, 2009, 37, (8), 3250–3258.

Shifts at the international gas market indicate that the transaction cost perspective provides better underpinnings for European gas regulation than the current neoclassical perspective. Three implications are that policymakers should: (1) allow alternative coordination measures to complement market exchange; (2) recognize that less than perfect competition outcomes may be optimal and (3) be more reticent in prescribing interventionist measures. Finally, the analysis provides the foundations for the empirical research required to complement this paper's theoretical approach.

Derived gaseous fuels

10/00552 Aerogel VO_x/MgO catalysts for oxidative dehydrogenation of propane

Mishakov, I. V. *et al. Catalysis Today*, 2009, 144, 278–284.

VO_x/MgO aerogel catalysts were synthesized using three different preparation methods: by mixing the aerogel MgO support with dry ammonium vanadate, by vanadium deposition from a precursor solution in toluene, and by hydrolysis of a mixture of vanadium and magnesium alkoxides followed by co-gelation and supercritical drying. The latter aerogel technique allowed us to synthesize mixed vanadium–magnesium hydroxides with the surface areas exceeding 1300 m^2/g. The synthesized catalysts were studied by a number of physicochemical methods (XRD, Raman spectroscopy, XANES and TEM). A common feature of all synthesized samples is the lack of V_2O_5 phase. In all cases vanadium was found to be a part of a surface mixed V–Mg oxide (magnesium vanadate), its structure depending on the synthesis method. The VO_x/MgO mixed aerogel sample had the highest surface area 340 m^2/g, showed higher catalytic activity and selectivity in oxidative dehydrogenation of propane compared to the catalysts prepared by impregnation and dry mixing. The addition of iodine vapour to the feed in 0.1–0.25 vol.% concentrations was found to increase to propylene yield by 40–70%.

10/00553 Bimetallic catalysts for the catalytic combustion of methane using microreactor technology

O'Connell, M. *et al. Catalysis Today*, 2009, 144, (3–4), 306–311.

Pt–W and Pt–Mo based catalysts were evaluated for methane combustion using a sandwich-type microreactor. Alumina washcoated microchannels were impregnated with platinum in combination with and promoted with tungsten and molybdenum and compared with commercially available Pt/Al_2O_3 catalysts. Catalysts were tested in the range of 300–700 °C with flow rates adjusted to GHSV of 74,000 h^{-1} and WHSV of 316 $L\,h^{-1}\,g^{-1}$. Catalysts containing tungsten were found to be the most active and the most stable possibly due to a metal interaction effect. A $Pt–W/\gamma\text{-}Al_2O_3$ containing 4.6 wt% Pt and 9 wt% W displayed the highest activity with full conversion at 600 °C and a selectivity to CO_2 of 99%.

10/00554 Biomass integrated gasification combined cycle for heat and power at ethanol plants

De Kam, M. J. *et al. Energy Conversion and Management*, 2009, 50, (7), 1682–1690.

Biomass integrated gasification combined cycle (BIGCC) technology can be used to generate process heat and significant amounts of electricity at dry-grind ethanol facilities by utilizing the ethanol process co-products and other biomass sources. These systems can reduce fuel costs for ethanol plants, improve the renewable energy balance of dry-grind ethanol production, and provide reliable renewable electricity for process use and for sale to the local utility. An Aspen Plus model of the dry-grind ethanol process is used as the basis for a subsequent gasification system model. A twin fluidized bed steam gasification configuration based on the SilvaGas process is used to generate synthesis gas. The results show that a dry-grind ethanol facility with a capacity of 190 million litres per year could produce 30.4 MW_e of power while supplying all its process heat needs using ethanol co-products and corn cobs. This configuration results in a three fold improvement in the amount of renewable energy produced per unit of fossil energy used compared to a conventional ethanol production process using natural gas.

10/00555 Conversion of hydrocarbon fuels to syngas in a short contact time catalytic reactor

Bobrova, L. *et al. Catalysis Today*, 2009, 144, (3–4), 185–200.

Some results of the theoretical and experimental research on the oxidative production of syngas from hydrocarbon fuels in catalytic reactors which operate at high temperatures and short contact times are presented. Pilot scale tests of the partial oxidation of methane, isooctane and gasoline have been carried out in nearly adiabatic conditions on structured catalysts developed at the Boreskov Institute of Catalysis and characterized by a low ($\leq$0.5 wt/wt%) content of noble metals. High yield of syngas and stable performance of the catalysts were revealed in the experiments. The details of interaction between chemical and physical processes inside adiabatic monolith reactor have been elucidated by mathematical modelling of the partial oxidation reaction on the base of catalyst detailed chemistry. The problems that emerged from the short contact time reactor operating on a pilot scale are also discussed.

10/00556 CO_2 reforming of CH_4 in coke oven gas to syngas over coal char catalyst

Zhang, G. *et al. Chemical Engineering Journal*, 2009, 156, (3), 519–523.

The CO_2 reforming of methane (in coke oven gas) on the coal char catalyst was performed in a fixed bed reactor at temperatures between 800 and 1200 °C under normal pressure. The effects of the coal char catalyst pretreatment and the ratio of CO_2/CH_4 were studied. Experimental results showed that the coal char was an effective catalyst for production of syngas, and addition of CO_2 did not enhance the CH_4 reforming to H_2. It was also found that the product gas ratio of H_2/CO is strongly influenced by the feed ratio of CO_2/CH_4. The modified coal char catalyst was more active during the CO_2–CH_4 reforming than the coal char catalyst based on the catalyst volume, furthermore the modified catalyst exhibited high activity in CO_2–CH_4 reforming to syngas. The conversion of methane can be divided into two stages. In the first stage, the conversion of CH_4 gradually decreased. In the second stage, the conversion of methane maintained nearly constant. The conversion of CO_2 decreased slightly during the overall reactions in CO_2–CH_4 reforming. The coal char catalyst is a highly promising catalyst for the CO_2 reforming of methane to syngas.

10/00557 Direct conversion of methane to synthesis gas using lattice oxygen of CeO_2–Fe_2O_3 complex oxides

Li, K. *et al. Chemical Engineering Journal*, 2009, 156, (3), 512–518.

Three kinds of complex oxides oxygen carriers (CeO_2–Fe_2O_3, CeO_2–ZrO_2 and ZrO_2–Fe_2O_3) were prepared and tested for the gas–solid reaction with methane in the absence of gaseous oxidant. These oxides were prepared by co-precipitation method and characterized by means of XRD, H_2-TPR and Raman. The XRD measurement shows that Fe_2O_3 particles well disperse on ZrO_2 surface and Ce–Zr solid solution forms in CeO_2–ZrO_2 sample. For CeO_2–Fe_2O_3 sample, only a small part of Fe^{3+} has been incorporated into the ceria lattice to form solid solutions and the rest left on the surface of the oxides. Low reduction temperature and low lattice oxygen content are observed over ZrO_2–Fe_2O_3 and CeO_2–ZrO_2 samples, respectively by H_2-TPR experiments. On the other hand, CeO_2–Fe_2O_3 shows a rather high reduction peak ascribed to the consuming of H_2 by bulk CeO_2, indicating high lattice oxygen content in CeO_2–Fe_2O_3 complex oxides. The gas–solid reaction between methane and oxygen carriers are strongly affected by the reaction temperature and higher temperature is benefit to the methane oxidation. ZrO_2–Fe_2O_3 sample shows evident methane combustion during the reducing of Fe_2O_3, and then the methane conversion is strongly enhanced by the reduced Fe species through catalytic cracking of methane. CeO_2–ZrO_2 complex oxides present a high activity for methane oxidation due to the formation of Ce–Zr solid solution, however, the low synthesis gas selectivity due to the high density of surface defects on Ce–Zr–O surface could also be observed. The highly selective synthesis gas (with H_2/CO ratio of 2) can be obtained over CeO_2–Fe_2O_3 oxygen carrier through gas–solid reaction at 800 °C. It is proposed that the dispersed Fe_2O_3 and Ce–Fe solid solution interact to contribute to the generation of synthesis gas. The reduced oxygen carrier could be re-oxidized by air and restored its initial state. The CeO_2–Fe_2O_3 complex oxides maintained very high catalytic activity and structural stability in successive redox cycles. After a long period of successive redox cycles, there could be more solid solutions in the CeO_2–Fe_2O_3 oxygen carrier, and that may be responsible for its favourable successive redox cycles performance.

10/00558 Effects of reaction conditions on hydrogen production and carbon nanofiber properties generated by methane decomposition in a fixed bed reactor using a NiCuAl catalyst

Suelves, I. *et al. Journal of Power Sources*, 2009, 192, (1), 35–42.

In this paper, the results obtained in the catalytic decomposition of methane in a fixed bed reactor using a NiCuAl catalyst prepared by the fusion method are presented. The influences of reaction temperature and space velocity on hydrogen concentration in the outlet gases, as well as on the properties of the carbon produced, have been investigated. Reaction temperature and the space velocity both increase the reaction rate of methane decomposition, but also cause an increase in the rate of catalyst deactivation. Under the operating conditions used, the carbon product is mainly deposited as nanofibres with textural properties highly correlated with the degree of crystallinity.

10/00559 Factors affecting steam gasification rate of low rank coal char in a pressurized fluidized bed

Matsuoka, K. *et al. Fuel Processing Technology*, 2009, 90, (7–8), 895–900.

A high-pressure bubbling fluidized bed reactor was used to study the steam gasification of coal char under pressure. Indonesian sub-bituminous coal char (Adaro) and Australian lignite char (Loy Yang) were gasified with steam in the reactor at temperatures below 1173 K and at total pressures ranging from 0.1 to 0.5 MPa. The steam gasification rates of the coal chars were determined by analysis of the gaseous products. Activation energies for the steam gasification of the chars were as high as about 250 kJ/mol, which suggests that the temperature dependence of the gasification was substantial. The apparent gasification rates under the study conditions were described by a Langmuir–Hinshelwood (L–H)-type equation. Analysis of the reaction kinetics on the basis of the L–H equation indicated that increasing steam pressure effectively increased the gasification rate.

10/00560 High-pressure co-gasification of coal with biomass and petroleum coke

Fermoso, J. *et al. Fuel Processing Technology*, 2009, 90, (7–8), 926–932.

The effects of the main operation variables (temperature, pressure and gasifying agent composition) on gas production and other process parameters, such as carbon conversion, cold gas efficiency and high heating value, during the steam–oxygen gasification of a bituminous coal were studied. It was observed that temperature and oxygen concentration were the most influential variables during the gasification process. In addition, co-gasification tests of binary blends of a bituminous coal with different types of biomass (up to 10%) and petroleum coke (up to 60%), as well as ternary blends of coal–petcoke–biomass (45–45–10%) were conducted in order to study the effect of blending on gas production and carbon conversion.

10/00561 Impact of torrefaction on syngas production from wood

Couhert, C. *et al. Fuel*, 2009, 88, (11), 2286–2290.

Torrefaction is a way to treat biomass before transportation or thermochemical conversion. It can be used to increase the energy content of wood or to facilitate grinding. The purpose of this paper was to quantify the impact of such a treatment on the behaviour of wood during gasification by steam at high temperature to produce syngas. The aspects of both gas yields and reaction kinetics were considered. Beechwood was submitted both to light torrefaction and severe torrefaction, using a specially designed crossed fixed bed reactor. The initial wood and the torrefied woods were first characterized, then gasified in a new laboratory high-temperature entrained flow reactor (HT-EFR) at 1400 °C for 2 s in an atmosphere containing 20 vol% steam in N_2. The syngas produced was then analysed. The experiments were modelled using a thermo-dynamical equilibrium approach. It was confirmed that torrefaction decreased the O/C ratio. The quantity of syngas produced increased with the severity of the torrefaction. The equilibrium approach describes the results satisfactorily. Gasification experiments carried out at a lower temperature – 1200 °C – indicated that the chars from torrefied woods are less reactive towards steam than the char from wood.

10/00562 Methane recovery from the anaerobic codigestion of municipal sludge and FOG

Kabouris, J. C. *et al. Bioresource Technology*, 2009, 100, (15), 3701–3705.

The anaerobic biodegradability of a mix of municipal primary sludge (PS), thickened waste activated sludge (TWAS) and fat, oil, and grease (FOG) was assessed using semi-continuous feed, laboratory-scale anaerobic digesters operated at mesophilic (35 °C) and thermophilic (52 °C) temperature. Addition of a large FOG fraction (48% of the total VS load) to a PS + TWAS mix, resulted in 2.95 times larger methane yield, 152 vs 449 mL methane @ STP/g VS added at 35 °C and 2.6 times larger methane yield, 197 vs 512 mL methane @ STP/g VS added at 52 °C. The high FOG organic load fraction was not inhibitory to the process. The results of this study demonstrate the benefit of sludge and FOG codigestion.

10/00563 The effect of downstream synthesis gas feeding on Fischer–Tropsch product distributions

Bucher, J. M. and Schwank, J. W. *Fuel Processing Technology*, 2009, 90, (7–8), 1009–1015.

The current study examines the effect of downstream synthesis gas feeding on Fischer–Tropsch product distributions in two series plug flow reactors over a precipitated iron catalyst. Synthesis gas at a constant H_2:CO ratio of 2.5 was fed into the entrance of a first reactor, and the resulting products were fed into a second reactor along with fresh synthesis gas of varying H_2:CO ratios (3, 2, 1, and 0.5). The selectivity of C_{5+} hydrocarbons in the downstream feeding cases was over two times lower than the corresponding 'top feeding' cases, in which an equivalent amount of synthesis gas was fed through both series reactors without the addition of downstream synthesis gas. These observations were attributed to the effects of bed residence time and H_2:CO ratios as influenced by the simultaneous water–gas shift reaction.

10/00564 The role of surface reactions on the active and selective catalyst design for bioethanol steam reforming

Benito, M. *et al. Journal of Power Sources*, 2009, 192, (1), 158–164.

In order to study the role of surface reactions involved in bioethanol steam reforming mechanism, a very active and selective catalyst for hydrogen production was analysed. The highest activity was obtained at 700 °C, temperature at which the catalyst achieved an ethanol conversion of 100% and a selectivity to hydrogen close to 70%. It also exhibited a very high hydrogen production efficiency, higher than 4.5 mol H_2 per mol of EtOH fed. The catalyst was operated at a steam to carbon ratio (S/C) of 4.8, at 700 °C and atmospheric pressure. No by-products, such as ethylene or acetaldehyde were observed. In order to consider a further application in an ethanol processor, a long-term stability test was performed under the conditions previously reported. After 750 h, the catalyst still exhibited a high stability and selectivity to hydrogen production. Based on the intermediate products detected by temperature programmed desorption and reaction (TPD and TPR) experiments, a reaction pathway was proposed. Firstly, the adsorbed ethanol is dehydrogenated to acetaldehyde producing hydrogen. Secondly, the adsorbed acetaldehyde is transformed into acetone via acetic acid formation. Finally, acetone is reformed to produce hydrogen and carbon dioxide, which were the final reaction products. The promotion of such reaction sequence is the key to develop an active, selective and stable catalyst, which is the technical barrier for hydrogen production by ethanol reforming.

10/00565 Thermodynamic evaluation of hydrogen production for fuel cells by using bio-ethanol steam reforming: effect of carrier gas addition

Hernández, L. and Kafarov, V. *Journal of Power Sources*, 2009, 192, (1), 195–199.

Omitting the influence of the addition of carrier gas to the reaction system for hydrogen production by bio-ethanol steam reforming can lead to wrong conclusions, especially when it is going to be made to scale. The effect of carrier gas addition to produce hydrogen using bio-ethanol steam reforming to feed fuel cells was evaluated. Thermodynamic calculations in equilibrium conditions were made, however the analysis derived from them can also be applied to kinetic conditions. These calculations were made by using the Aspen-HYSYS software at atmospheric pressure and different values of temperature, water/ethanol molar ratios, and inert (argon)/(water/ethanol) molar ratios. The addition of inert carrier gas modifies the concentrations of the reaction products in comparison to those obtained without its presence. This behaviour occurs because most of the reactions which take place in bio-ethanol steam reforming have a positive difference of moles. This fact enhances the system sensitivity to inert concentration at low and moderated temperatures (<700 °C). At high values of temperature, the inert addition does not influence the composition of the reaction products because of the predominant effect of inverse water-gas shift reaction.

LNG

10/00566 Utilization of the cryogenic exergy of liquid natural gas (LNG) for the production of electricity

Szargut, J. and Szczygiel, I. *Energy*, 2009, 34, (7), 827–837.

Liquid natural gas (LNG) delivered by means of sea-ships is compressed and then evaporated before its introduction to the system of pipelines. The possibilities of the utilization of cryogenic exergy of LNG for electricity production without any additional combustion of any its portion, have been analysed. Three variants of the plant have been investigated. A cascade system with two working fluids has been analysed in two first of them. The economic optimization proved that the optimum temperature difference in the LNG evaporation is higher than initially assumed. Therefore, a third variant of the plant has been analysed, with ethane as a single working fluid. Only the third variant has been analysed in detail. The economic optimization of the minimum heat transfer temperature difference (pinch value) in particular heat exchangers has been performed and then the optimum heat transfer area of heat exchangers has been calculated. The influence of the changing ambient temperature on the efficiency of the cold power plant has been analysed. The own cost of the produced electricity, the annual profit and the pay-back of the plant have been evaluated. The attained reduction of CO_2 emission in national economy has been calculated. The analysis of the sensitivity of economical profit on the deviation of economic data has been determined.

Hydrogen generation and storage

10/00567 An onboard hydrogen generation method based on hydrides and water recovery for micro-fuel cells

Zhu, L. *et al. Journal of Power Sources*, 2009, 192, (2), 556–561.

Micro-proton exchange membrane fuel cells are considered to be the next generation power sources for micro-scale power applications, but onboard hydrogen storage and generation with high energy density at the small scale is still a technical barrier. This paper introduces a hydrogen generation method based on an onboard hydride fuel and a by-product water recovery mechanism for micro-hydrogen PEM fuel cells. The water recovery is carried out by water diffusion from the more humid cathode side to the less humid anode side through the proton exchange membrane. The micro-fuel cells based on this water recovery method were constructed and tested. The results demonstrate that the relative humidity has a significant affect on the fuel cell performance as well as the opening area on the cover layer, the type of hydrides, and the thickness of the Nafion membrane also can affect the fuel cell performance. A 10 mm^3 prototype water recovery micro-fuel cell has been built and tested, and the device has produced a maximum power density of 104 $W L^{-1}$ and a maximum energy density of 313 $W h L^{-1}$.

10/00568 Biohydrogen production from pig slurry in a CSTR reactor system with mixed cultures under hyper-thermophilic temperature (70 °C)

Kotsopoulos, T. A. *et al. Biomass and Bioenergy*, 2009, 33, (9), 1168–1174.

A continuous stirred tank reactor (CSTR) (750 cm^3 working volume) was operated with pig slurry under hyper-thermophilic (70 °C) temperature for hydrogen production. The hydraulic retention time (HRT) was 24 h and the organic loading rate was 24.9 $g d^{-1}$ of volatile solid (VS). The inoculum used in the hyper-thermophilic reactor was sludge obtained from a mesophilic methanogenic reactor. The continuous feeding with active biomass (inoculum) from the mesophilic methanogenic reactor was necessary in order to achieve hydrogen production. The hyper-thermophilic reactor started to produce hydrogen after a short adapted period of 4 days. During the steady state period the mean hydrogen yield was 3.65 $cm^3 g^{-1}$ of volatile solid added. The high operation temperature of the reactor enhanced the hydrolytic activity in pig slurry and increased the volatile fatty acids production. The short HRT (24 h) and the hyper-thermophilic temperature applied in the reactor were enough to prevent methanogenesis. No pre-treatment methods or other control methods for preventing methanogenesis were necessary. Hyper-thermophilic hydrogen production was demonstrated for the first time in a CSTR system, fed with pig slurry, using mixed culture. The results indicate that this system is a promising one for biohydrogen production from pig slurry.

10/00569 Design and economical analysis of hybrid PV–wind systems connected to the grid for the intermittent production of hydrogen

Dufo-López, R. *et al. Energy Policy*, 2009, 37, (8), 3082–3095.

In this paper, several designs of hybrid PV–wind (photovoltaic–wind) systems connected to the electrical grid, including the intermittent production of hydrogen, are shown. The objective considered in the design is economical to maximize the net present value (*NPV*) of the system. A control strategy has been applied so that hydrogen is only produced by the electrolyser when there is an excess of electrical energy that cannot be exported to the grid (intermittent production of hydrogen). Several optimization studies based on different scenarios have been carried out. After studying the results – for systems with which the produced hydrogen would be sold for external consumption – it can be stated that the selling price of hydrogen should be about 10 €/kg in areas with strong wind, in order to get economically viable systems. For the hydrogen-producing systems in which hydrogen is produced when there is an excess of electricity and then stored and later used in a fuel cell to produce electricity to be sold to the grid, even in areas with high wind speed rate, the price of electrical energy produced by the fuel cell should be very high for the system to be profitable.

10/00570 Efficient production of hydrogen by photo-induced reforming of glycerol at ambient conditions

Daskalaki, V. M. and Kondarides, D. I. *Catalysis Today*, 2009, 144, (1–2), 75–80.

Photocatalytic reforming of aqueous solutions of glycerol at ambient conditions has been investigated with the use of Pt/TiO_2 photocatalysts and a solar light-simulating source. The effects of platinum loading, photocatalyst content in suspension, glycerol concentration, solution pH and temperature on the reaction rate have been studied in detail. Results obtained show that the reaction proceeds with intermediate production of methanol and acetic acid and eventually results in complete conversion of glycerol to H_2 and CO_2. Optimal results are obtained for TiO_2 photocatalyst loaded with 0.1–0.5 wt.% Pt, whereas further increase of platinum content has a detrimental effect on photocatalytic performance. The reaction is favoured over neutral and basic solutions, compared to acidic solutions, and the reaction rate increases substantially with increasing temperature from 40 to 60–80 °C. For high glycerol concentrations ($\sim 1\,mol\,L^{-1}$) the rate of hydrogen evolution is about two orders of magnitude higher, compared to that obtained for pure water, rendering the process suitable for application. It is concluded that glycerol photoreforming at ambient conditions may provide an efficient and low cost method for the production of renewable hydrogen.

10/00571 Generation of hydrogen gas from polyethylene mechanically milled with Ni-doped layered double hydroxide

Tongamp, W. *et al. Fuel Processing Technology*, 2009, 90, (7–8), 909–913.

A process for generating hydrogen gas from polyethylene (PE) by milling and heating with Ni-doped layered double hydroxide (LDH), which was prepared also by a mechanochemical route of two-step milling operation, was reported in this work. A mixture of PE and the prepared Ni-doped LDH was first milled in a planetary ball mill for 1 h followed by heating the milled product to 700 °C under He/Ar gas environment for hydrogen emission. Characterizations by a set of analytical methods of X-ray diffraction (XRD), thermogravimetry-mass spectroscopy (TG-MS) and gas chromatography (GC) were performed on the milled and heated samples to monitor the process. Gaseous products obtained during heating mainly consisted of H_2, CH_4, CO, CO_2 with H_2 concentration over 80% between 450 and 550 °C. Such a process could be developed to treat hydrocarbon based solid wastes for hydrogen generation.

10/00572 Hydrogen production by chemical-looping reforming in a circulating fluidized bed reactor using Ni-based oxygen carriers

de Diego, L. F. *et al. Journal of Power Sources*, 2009, 192, (1), 27–34.

This work presents the experimental results obtained during auto-thermal chemical-looping reforming (CLR) in a 900 W_{th} circulating fluidized bed reactor under continuous operation using methane as fuel. Two oxygen carriers based on NiO and supported on γ-Al_2O_3 and α-Al_2O_3 were used during more than 50 h of operation with each oxygen carrier. During operation the effect of different operating variables, like fuel reactor temperature, H_2O/CH_4 molar ratio and solid circulation rate, on CH_4 conversion and gas product distribution was analysed. It was found that in all operating conditions CH_4 conversion was very high (>98%) and the most important variable affecting to the gas product distribution was the solid circulation rate, that is, NiO/CH_4 molar ratio. Similar gas product distribution was obtained working with both oxygen carriers although at different NiO/CH_4 molar ratios. The oxygen carrier of NiO on α-Al_2O_3 needed lower NiO/CH_4 molar ratio to reach the same gas product composition than the oxygen carrier of NiO on γ-Al_2O_3. Working at optimal operating conditions, 2.5 moles of H_2 per mol of CH_4 could be obtained in this process. During operation the oxygen carrier particles maintained their physical and chemical properties. These results suggest that these oxygen carriers could have a high durability, being suitable oxygen carriers for a CLR system.

10/00573 H_2 rich product gas by steam gasification of biomass with in situ CO_2 absorption in a dual fluidized bed system of 8 MW fuel input

Koppatz, S. *et al. Fuel Processing Technology*, 2009, 90, (7–8), 914–921.

The steam gasification of solid biomass by means of the absorption enhanced reforming process (AER process) yields a high quality product gas with increased hydrogen content. The product gas can be used for a wide range of applications which covers the conventional combined heat and power production as well as the operation of fuel cells, the conversion into liquid fuels or the generation of synthetic natural gas and hydrogen. On the basis of a dual fluidized bed system, steam gasification of biomass is coupled with *in situ* CO_2 absorption to enhance the formation of hydrogen. The reactive bed material (limestone) used in the dual fluidized bed system realizes the continuous CO_2 removal by cyclic carbonation of CaO and calcination of $CaCO_3$. Biomass gasification with *in situ* CO_2 absorption has been substantially proven in pilot plant scale of 100 kW fuel input. The present paper outlines the basic principles of steam gasification combined with the AER process the investigations in reactive bed materials, and concentrates further on the first time application of the AER process on industrial scale. The first time application has been carried out within an experimental campaign at a combined heat and power plant of 8 MW fuel input. The results are outlined with regard to the process conditions and achieved product gas composition. Furthermore, the results are compared with standard steam gasification of biomass as well as with application of absorption enhanced reforming process at pilot plant scale.

10/00574 *In situ* generation of hydrogen from water by aluminum corrosion in solutions of sodium aluminate

Soler, L. *et al. Journal of Power Sources*, 2009, 192, (1), 21–26.

A new process to obtain hydrogen from water using aluminium in sodium aluminate solutions is described and compared with results obtained in aqueous sodium hydroxide. This process consumes only water and aluminium, which are raw materials much cheaper than other compounds used for *in situ* hydrogen generation, such as hydrocarbons and chemical hydrides, respectively. As a consequence, this process could be an economically feasible alternative for hydrogen to supply fuel cells. Results showed an improvement of the maximum rates and yields of hydrogen production when $NaAlO_2$ was used instead of NaOH in aqueous solutions. Yields of 100% have been reached using $NaAlO_2$ concentrations higher than 0.65 M and first order kinetics at concentrations below 0.75 M has been confirmed. Two different heterogeneous kinetic models are verified for $NaAlO_2$ aqueous solutions. The activation energy (E_a) of the process with $NaAlO_2$ is $71\,kJ\,mol^{-1}$, confirming a control by a chemical step. A mechanism unifying the behaviour of Al corrosion in NaOH and $NaAlO_2$ solutions is presented. The application of this process could reduce costs in power sources based on fuel cells that nowadays use hydrides as raw material for hydrogen production.

10/00575 Influence on hydrogen production of the minor components of natural gas during its decomposition using carbonaceous catalysts

Pinilla, J. L. *et al. Journal of Power Sources*, 2009, 192, (1), 100–106.

In this work, the catalytic decomposition of the minor hydrocarbons present in natural gas, such as ethane and propane, over a commercial carbon black (BP2000) is studied. The influence of the reaction temperature on the product gas distribution was investigated. Increasing reaction temperatures were found to increase both hydrocarbon conversion and hydrogen selectivity. Carbon produced by ethane and propane was predominantly deposited as long filaments formed by spherical aggregates with diameters on the order of nanometres. Furthermore, the influence of ethane and propane on methane decomposition over BP2000 was also investigated, showing enrichment in hydrogen concentration with the addition of small amounts of these hydrocarbons in the feed. Additionally, the positive catalytic effect of H_2S on methane decomposition over BP2000 is addressed.

10/00576 On-board hydrogen storage and production: an application of ammonia electrolysis

Boggs, B. K. and Botte, G. G. *Journal of Power Sources*, 2009, 192, (2), 573–581.

On-board hydrogen storage and production via ammonia electrolysis was evaluated to determine whether the process was feasible using galvanostatic studies between an ammonia electrolytic cell (AEC) and a breathable proton exchange membrane fuel cell (PEMFC). Hydrogen-dense liquid ammonia stored at ambient temperature and pressure is an excellent source for hydrogen storage. This hydrogen is released from ammonia through electrolysis, which theoretically consumes 95% less energy than water electrolysis; $1.55\,Wh\,g^{-1}\,H_2$ is required for ammonia electrolysis and $33\,Wh\,g^{-1}\,H_2$ for water electrolysis. An ammonia electrolytic cell (AEC), comprised of carbon fibre paper (CFP) electrodes supported by Ti foil and deposited with Pt–Ir, was designed and constructed for electrolysing an alkaline ammonia solution. Hydrogen from the cathode compartment of the AEC was fed to a polymer exchange membrane fuel cell (PEMFC). In terms of electric energy, input to the AEC was less than the output from the PEMFC yielding net electrical energies as high as $9.7 \pm 1.1\,Wh\,g^{-1}\,H_2$ while maintaining H_2 production equivalent to consumption.

10/00577 Photocatalytic hydrogen production by liquid- and gas-phase reforming of CH_3OH over flame-made TiO_2 and Au/TiO_2

Chiarello, G. L. *et al. Catalysis Today*, 2009, 144, (1–2), 69–74.

TiO_2 and 1% Au/TiO_2 powders, synthesised by flame spray pyrolysis and possessing high specific surface area ($106\,m^2\,g^{-1}$) and anatase content (*ca.* 90%), were tested as photocatalysts in hydrogen production from methanol photoreforming, employing a closed recirculation apparatus. The irradiated photoreactor consisted either in a quartz vessel containing an aqueous suspension of the photocatalyst, or in a newly set-up Plexiglas cell, containing the same amount of catalyst immobilised on quartz grains, which was continuously fed with methanol/water vapours. The gas-phase composition during irradiation was analysed by gas chromatography and quadrupolar mass spectrometry, which allowed the identification of formaldehyde as the only intermediate species. The photocatalytic activity of the flame-made materials was higher than that of commercial Degussa P25 TiO_2 and of 1% Au/P25 obtained via deposition of preformed gold nanoparticles on P25. In particular, a 30 times higher photocatalytic hydrogen production was obtained upon gold addition to TiO_2. Furthermore, a 30% higher reaction rate was attained with the vapour phase reactor, i.e. in the absence of liquid-phase mass transfer rate limitations, ensuring the production of up to 10.2 mmol of H_2 h^{-1} g_{cat}^{-1}, with an apparent photon efficiency of 6.3%.

10/00578 Separation and storage of hydrogen by steam-iron process: effect of added metals upon hydrogen release and solid stability

Lorente, E. *et al. Journal of Power Sources*, 2009, 192, (1), 224–229.

During the last decade, the steam-iron process has re-emerged as a possible way to separate and/or storage pure hydrogen through the use of metallic oxides subjected to redox cycles. The most renamed candidate to achieve this goal has traditionally been iron oxide. Nevertheless, the study of its behaviour along repetitive reduction/oxidation stages has shown that the hydrogen storage density diminishes abruptly from the first cycle on. To cope with this problem, the inclusion of a second metal oxide in the solid structure has been tried. Isothermal experiments of reduction with hydrogen rich flows and oxidation with steam have been carried out with Al, Cr and Ce as second metals, in nominal amounts from 1% to 10 mol% added to the hematite structure, which has been synthesized in laboratory by coprecipitation. Series of up to seven cycles (reductions followed by oxidations in a thermogravimetric system acting as differential reactor for the gas) have shown that to that point, an almost repetitive behaviour can be obtained, recovering the magnetite (Fe_3O_4) structure after each oxidation step. Since the second metal oxide does not intervene in the reduction/oxidation process, the optimum content of second metal for each species has been determined with the aim to keep the highest hydrogen storage density along cycles.

10/00579 Transportation of hydrogen molecules using carbon nanotubes in torsion

Wang, Q. *Carbon*, 2009, 47, (7), 1870–1873.

The transportation of hydrogen molecules using carbon nanotubes subjected to torsion is studied with molecular dynamics. Molecular dynamics simulations reveal that the transportation in a (10, 0) carbon nanotube is a result of the van der Waals effect through the propagation of the kink initiated at the onset of the tube torsional buckling. In addition, the applied torsional loading rate has an obvious effect on the orientation of the molecular transportation. On the other hand, the motion of the molecules in a (10, 10) carbon nanotube is found to be less oriented. The mechanism of the transportation in the larger carbon nanotube is investigated through the transform of the collapsed wall of the tube in the dynamic process of the torsional buckling.

04 BY-PRODUCTS RELATED TO FUELS

10/00580 Activated carbon + HFC 134a based two stage thermal compression adsorption refrigeration using low grade thermal energy sources

Banker, N. D. *et al. Applied Thermal Engineering*, 2009, 29, (11–12), 2257–2264.

A thermodynamic analysis is presented for the two stage thermal compression process for an adsorption refrigeration cycle with HFC-134a as the working fluid and activated carbon as the adsorbent. Three specimens of varying achievable packing densities were evaluated. The influence of evaporating, condensing/adsorption and desorption temperatures was assessed through three performance indicators, namely, the uptake efficiency, the coefficient of performance and the exergetic efficiency. Conditions under which a two-stage thermal compression process performs better than the single-stage unit are identified. It is concluded that two stage thermal compression will be a viable proposition when the heat source temperature is low or when adsorption characteristics are weak or when adequate packing densities are difficult to realize.

10/00581 Carbon monoxide partial pressure effects on the metabolic process of syngas fermentation

Hurst, K. M. and Lewis, R. S. *Biochemical Engineering Journal*, 2009, 48, (2), 159–165.

The fermentation of syngas (CO, CO_2, and H_2) produced from biomass gasification for the production of ethanol has received increased attention due to the low cost and abundance of cellulosic feedstocks. Since CO plays a critical role in the available reducing equivalents and carbon conversion, this work assessed the effects of constant CO partial pressure (P_{CO}), ranging from 0.35 to 2.0 atm, on cell growth, acetic acid production, and ethanol production using *Clostridium carboxidivorans* P7^T. Several key findings included: (a) the maximum cell concentration increased with increasing P_{CO}, increasing 440% with a P_{CO} increase from 0.35 to 2.0 atm, (b) ethanol production changed from non-growth-associated to growth-associated with increasing P_{CO}, (c) acetic acid production (gram acetic acid per gram cells) decreased for $P_{CO} \geq 1.05$ atm relative to $P_{CO} \leq 0.70$ atm, and (d) acetic acid appeared to be converted in the latter growth stages for P_{CO} of 1.35 and 2.0 atm. Several explanations point to the potential importance of P_{CO} and the P_{CO} to P_{CO2} ratio on electron and ATP production. Since gasification processes that generate syngas could result in differing gas partial pressures, process variations could significantly change growth and product formation as evidenced by metabolic changes observed in this work due to changing P_{CO} and/or the P_{CO} to P_{CO2} ratio.

10/00582 Colour measurement as a proxy method for estimation of changes in phase and chemical composition of fly ash formed by combustion of coal

Raclavska, H. *et al. Fuel*, 2009, 88, (11), 2247–2254.

Influence of technology on colour changes of fly ashes was studied in relationships with their chemical and phase composition. Dry bottom boilers at the Detmarovice Power Plant (the Czech Republic) were selected for this study. Combustion tests were performed using mixture of coal and mineral oil residues at the minimum and maximum output of the power plant. Fly ashes for chemical analysis, phase analysis and colour measurements were sampled from the four sections of electrostatic fly ash precipitator. Colour parameters indicate relationships with concentrations of elements which are preferentially bound in silicate matrix. The maximum output of power plant increases the concentration of glass which has decisive influence on values of colour parameters. The changes of colour parameters can indicate the conditions of the technological process. Relationships between colour and constituents of the fly ash are expressed by CIE Lab colour parameters.

10/00583 Comparison of the characteristics of bottom ash and fly ash from a medium-size (32 MW) municipal district heating plant incinerating forest residues and peat in a fluidized-bed boiler

Dahl, O. *et al. Fuel Processing Technology*, 2009, 90, (7–8), 871–878.

In this study, the physical and chemical properties of bottom ash and fly ash originating from the co-combustion of biomass-derived fuels (i.e. wood chips, sawdust, bark, and peat) from a 32 MW fluidized bed boiler at a municipal district heating plant were investigated. Silicate minerals were predominant in the bottom ash and calcium minerals in the fly ash, with most of the inorganic nutrients and heavy metals being enriched in the fly ash. The enrichment factors for heavy metals in the fly ash varied between 0.2 for silicon and 16.3 for lead, and for plant nutrients, between 1.5 for phosphorous and 108 for potassium. However, all heavy metal concentrations in both the bottom ash and fly ash were significantly lower than the current Finnish limit for maximum allowable heavy metal concentrations for forest fertilizers, which came into force in March 2007. According to the particle size distribution, the mass loadings of heavy metals in the fly ash were more than 90% contributed by the smallest particle size fraction lower than 0.074 mm. In the bottom ash, between 83.6 and 91.9% of the mass loadings of heavy metals were contributed by the particle size fraction between 0.5 and 2.0 mm.

10/00584 Conversion of greenhouse gases into syngas via combined effects of discharge activation and catalysis

Zhang, A.-J. *et al. Chemical Engineering Journal*, 2009, 156, (3), 601–606.

The topics on conversion and utilization of methane and carbon dioxide are important issues in tackling the global warming effect from the two greenhouse gases. In the present study, pure plasma and plasma catalytic activation of methane and carbon dioxide were investigated for syngas production. For pure plasma process, the effects of discharge power, CH_4/CO_2 ratios in the feed, total flow rate, as well as the concentration of the balanced gas of Ar were studied. Ar in the feed has great effects on the conversion and the stability of the reaction. At 120 °C and atmospheric pressure, the conversion of CH_4 increased from 39% to 56% and that of CO_2 increased from 23% to 30% when the Ar content in the feed increased from 0% to 50%, whereas Ar showed little effect on the H_2/CO ratios in the products. Moreover, the conversions of CH_4 and CO_2 remained unchanged within the testing hours in the presence of 50% of Ar, which was contrastive with those obtained without Ar in the feed. When Cu–Ni/Al_2O_3 catalyst was filled in the discharge gap at 450 °C, the synergism between the catalyst and dielectric-barrier discharge (DBD) plasma was achieved. Conversions of CH_4 for plasma alone, plasma-catalysis and catalysis alone were 13%, 69% and 10%, respectively. Selectivities to CO and H_2 under the plasma-catalytic process were, respectively, 76% and 57%.

10/00585 Effects of Chinese dolomites on tar cracking in gasification of birch

Yu, Q.-Z. *et al. Fuel*, 2009, 88, (10), 1922–1926.

To minimize tar in the producer gas from birch gasification at 700, 750 and 800 °C, four Chinese dolomites (Zhenjiang, Nanjing, Shanxi, Anhui) and a Swedish dolomite (Sala) used as reference were studied in a laboratory-scale atmospheric fluidized bed gasifier. The gasifier was equipped with a downstream fixed catalyst bed. The results imply that all dolomites but Anhui dolomite effectively decompose tar into gases. Anhui dolomite showed a low catalytic capacity to crack tar produced at 700 and 800 °C. The influence of various ratios of steam to biomass on tar content in the producer gas after passing over dolomite was studied. The tar cracking efficiency of the dolomites did not improve significantly with the ratio of steam to biomass in the region 0.11–0.52.

10/00586 Experimental and statistical analysis of trichloroethylene adsorption onto activated carbon

Erto, A. *et al. Chemical Engineering Journal*, 2009, 156, (2), 353–359.

Adsorption processes have long been used in water and wastewater treatment and a deterministic approach has been often adopted for the analysis of fundamental mechanisms. In this research, a new approach based on statistical treatment of modelling data is adopted for the analysis of trichloroethylene (TCE) adsorption on granular activated carbon (GAC) from synthetic groundwater. The work starts from an experimental analysis aimed at the assessment of the influence of thermodynamic parameters (concentration, pH, salinity, temperature and the presence of an organic non-ionic compound, i.e. ethyl acetate) on TCE adsorption capacity. A wide range of process parameters have been considered to simulate highly polluted groundwater, as when leachate infiltrations occur at solid waste landfill. Experimental results show that adsorption capacity decreases by increasing the temperature and the ethyl acetate concentration, while neither pH nor salinity have any influence. A thorough understanding of adsorption mechanism and the individuation of the model with highest physical and mathematical significance is carried out by a thermodynamic analysis and a statistical methodology based on analysis of variance (ANOVA). The latter indicates that in dilute solutions the Freundlich model is the best data fitting model for TCE adsorption, among those which are commonly adopted.

10/00587 Hydro-treatment of Athabasca vacuum tower bottoms in supercritical toluene with microporous activated carbons and metal–carbon composite

Xu, C. *et al. Fuel*, 2009, 88, (11), 2097–2105.

Highly porous biomass-derived activated carbon (denoted as BAC) and the BAC-supported NiMo catalyst (Ni–Mo/BAC), as well as a novel highly porous metal–carbon composite (Ni–Mo–BAC) were prepared and tested for hydro-treatment of Athabasca vacuum tower bottoms (AVTB) in supercritical toluene at 380 °C. All the BAC-based catalysts were very effective for HDAs of AVTB, converting asphaltenes to maltenes (MA) with toluene insoluble (TI) as a by-product. The BAC and Ni–Mo–BAC catalysts, having much greater BET surface areas and containing significant amount of micropores, were exceptionally active for HDAs of the AVTB in supercritical toluene, leading to an AS removal efficiency of 68% and 79%, respectively. The hydro-treatment of AVTB in supercritical toluene with the BAC-based catalysts also led to 21–25% S removal and 30–32% N removal. The metal–carbon composite (Ni–Mo–BAC) showed exceptionally high activity in HDAs of AVTB in supercritical toluene, which might be accounted for by its unique properties of maintaining at a high BET surface area and porous structure during the AVTB treatment. The possible roles of the carbon-based catalysts and supercritical toluene in hydro-conversion of AVTB were discussed.

10/00588 Modifying activated carbon with hybrid ligands for enhancing aqueous mercury removal

Zhu, J. *et al. Carbon*, 2009, 47, (8), 2014–2025.

In an effort to enhance mercury (Hg) removal from the aqueous solution, activated carbon (AC) was modified by a combined treatment of nitric acid and thionyl chloride, followed by the reaction with ethylenediamine, to introduce N-, S-, and Cl-containing functional groups. The modified activated carbon (MAC) was characterized by SEM-EDS, FT-IR, XPS, elemental analyser, and potentiometry. Kinetics and equilibrium isotherms of Hg sorption by MAC were determined in batch experiments. Characterization indicated that additions of the organic–inorganic ligands onto AC surface by treatment were effective, likely through the acyl chloride–carbon reactions. Potentiometric titration showed that the modifications introduced more negative surface charges favouring cation sorption. Kinetics and isotherm studies demonstrated that the Hg sorption by MAC was faster (<30 min) and higher (>200%) than that by AC, suggesting a high affinity of MAC for Hg ions. The sorption by MAC occurred in a wider pH range (4–10 vs 5–7), and low ionic strength appeared to enhance Hg sorption. The sorption isotherms were best described by Freundlich model, and enhanced Hg sorption by MAC was primarily accomplished by the coordinations of ligand atoms (O, N and S) with Hg ions through the mechanisms of surface complexation, reduction, and ion exchange.

05 NUCLEAR FUELS

Scientific, technical

10/00589 Accelerator breeder reactors

Lodhi, M. A. K. and Shubov, M. *Annals of Nuclear Energy*, 2009, 36, (6), 837–843.

In this work, the authors briefly describe the accelerator breeder reactors (ABR) and their possible uses both for production of energy and isotopes. This study indicates that ABRs can produce fuel, which would generate 2–15 times the electrical energy, ABRs consume. The energy gain depends on the type of ABR used. ABRs should also have several important advantages in safety over the modern breeder reactors. First, they have criticality less then 1, which makes an accident less likely. Second, they can be turned off any moment when their accelerator is turned off.

10/00590 Enthalpy–entropy graph approach for the classification of faults in the main power system of a closed Brayton cycle HTGR

du Rand, C. P. *et al. Annals of Nuclear Energy*, 2009, 36, (6), 703–711.

An enthalpy–entropy (*h–s*) graph approach for the classification of faults in a new generation type high temperature gas-cooled reactor (HTGR) is presented. The study is performed on a 165 MW model of the main power system (MPS) of the pebble bed modular reactor (PBMR) that is based on a single closed-loop Brayton thermodynamic cycle. In general, the *h–s* graph is a useful tool in order to understand and characterize a thermodynamic process. It follows that it could be used to classify system malfunctions from fault patterns (signatures) based on a comparison between actual plant graphs and reference graphs. It is demonstrated that by applying the *h–s* graph approach, different fault signatures are derived for the examined fault conditions. The fault conditions that are considered for the MPS are categorized in three fault classes and comprise the main flow bypass of the working fluid, an increase in main flow resistance, and a decrease in component effectiveness or efficiency. The proposed approach is specifically illustrated for four single and two multiple fault conditions during normal power operation of the plant. The simulation of the faults suggests that it is possible to classify all of the examined system malfunctions correctly with the *h–s* graph approach, using only single reference fault signatures.

10/00591 EQL3D: ERANOS based equilibrium fuel cycle procedure for fast reactors

Krepel, J. *et al. Annals of Nuclear Energy*, 2009, 36, (5), 550–561.

The advanced fast reactors of the fourth generation should be capable to breed their own fuel from poorly fissile ^{238}U and to recycle the actinides from their own spent fuel. However, this recycling or actually the closure of fuel cycle has negative impact on the safety parameters. The goal of this work is to develop a numerical tool, which can simulate and confirm the capability of these reactors to operate with closed fuel cycle, and which can evaluate their safety parameters. The tool is named equilibrium fuel cycle procedure for fast reactors (EQL3D) and is based on the ERANOS 2.1 code platform. Equilibrium cycle or virtually equilibrium method for considering the homogeneous recycling of actinides is a known approach; however, in EQL3D the equilibrium method is newly applied for hexagonal-z 3D and r-z 2D core geometries and typically 33 energy-group neutron-flux calculations. The utilization of hexagonal-z 3D geometry enables to characterize the equilibrium cycle for complex reloading patterns within a multi-batch scheme. Furthermore, EQL3D enables comparison of the advanced fast reactors on a common basis of their equilibrium cycle reactivity swing, fuel composition, breeding gain and safety-related parameters. The gas-cooled fast reactor (GFR) was selected for verification and optimization of the EQL3D procedure. The GFR geometry was based on an international neutronics benchmark with a simple setup and potential for latter upgrade. It was used to show the impact of several EQL3D options, e.g. different isotope evolution models, geometry selection, or cross-section recalculation frequency, on the equilibrium parameters. The results demonstrate the capability of the procedure to calculate the equilibrium fuel cycle for advanced fast reactors. Among others, also the ability of GFR benchmark core to be operated with closed fuel cycle is shown.

10/00592 Fixation of radioactive chemical sludge in a matrix containing cement and additives

Sinha, P. K. *et al. Annals of Nuclear Energy*, 2009, 36, (5), 620–625.

The radioactive chemical sludge stored in a clariflocculator (CF) at CWMF has to be fixed in cement before disposal in Near Surface Disposal Facilities (NSDF). The gross β–γ and ^{137}Cs content associated with the sludge were typically of the order of 10^3–10^4 Bq/g while the α content was about 10^2 Bq/g. The total solid content of the sludge varied in the range 3–13% by weight. Experiments were carried out to optimize the ratio of sludge to cement, study the effect of additives like vermiculite and bentonite and characterize the resulting cement blocks with respect to leaching and compressive strength. Results indicated that the blocks obtained on mixing the sludge only with cement in the ratio 1.0:1.5 by weight showed good compressive strength but poor leaching characteristics in tap water. Addition of bentonite or vermiculite (5% of weight of cement) reduced the compressive strength but improved the leaching behaviour. The effects were subdued in case of bentonite but were very significant in case of vermiculite. The effect of addition of both bentonite and vermiculite (each 5% of weight of the cement) was comparable to that of vermiculite alone and hence, addition of only vermiculite to cement was recommended in order to keep the leaching minimum.

10/00593 Optimization of recompression S-CO$_2$ power cycle with reheating

Sarkar, J. and Bhattacharyya, S. *Energy Conversion and Management*, 2009, 50, (8), 1939–1945.

In the present study, optimization of compressor pressure ratio and intermediate pressure between HP and LP turbines leading to maximum thermal efficiency is implemented for a supercritical CO$_2$ recompression cycle with reheating applicable to next generation nuclear reactors. Effects of various operating conditions and component performances on the optimal values and cycle efficiency are studied as well. Finally, a comparison between supercritical CO$_2$ recompression cycles with and without reheating is presented. The optimization of recompression mass fraction shows that the present cycle configuration yields maximum thermal efficiency for nearly equal heat capacity values of both fluids in LTR. The effect of maximum cycle temperature on the optimum pressure ratio is negligible for lower values of minimum cycle temperature and maximum pressure, and the effect becomes significant with an increase in these parameters. Results show that the thermal efficiency improves with a decrease in minimum cycle temperature and with increase in maximum cycle temperature and pressure. The optimum intermediate pressure is exhibited to be higher than the geometric mean value between minimum and maximum pressure and a simple empirical correlation useful for optimum design is presented. The maximum efficiency improvement using reheating is calculated as 3.5% at optimum conditions.

Economics, policy, supplies, forecasts

10/00594 A review and comparison of fracture mineral investigations and their application to radioactive waste disposal

Blyth, A. R. *et al. Applied Geochemistry*, 2009, 24, (5), 821–835.

A compilation and comparison of fracture mineral studies from the Canadian and Fennoscandian Shields and the French Massif Central shows many similarities indicating larger external control over fracture mineral deposition, with different rock types exerting local controls. The sites investigated represent a wide range of geological settings, and host rock types ranging from felsic intrusive and extrusives to ultramafic intrusives and volcanics that span an age range from 2.5 to 0.36 Ga. Typical fracture minerals found at Canadian Shield sites include calcite, quartz, chlorite and clays, and these do not appear to be dependant on age, erosional depth or geological environment. The Fennoscandian Shield has a much larger variety of fracture filling minerals with epidote, zeolites, prehnite, fluorite, pyrrhotite, Fe oxides, serpentine, graphite, magnesite and barite in addition to the minerals typically found at Canadian Shield sites. The major control on fracture mineral type is most likely variations in rock type, and fluid chemistry and temperature. The C and O isotopic range of calcite is very similar among sites. Late-stage hydrothermal calcite, with strongly depleted δ^{18}O values, is common at many sites. All of the sites have calcite with δ^{18}O isotopic values in the range of −5 to −20‰ PDB, indicative of formation from meteoric water or basinal brines that have undergone varying degrees of water/rock interaction. One Canadian and a few Swedish sites have calcite in the shallower portion of the rock that shows isotopic evidence of dissolution and re-precipitation in equilibrium with the present-day waters. There are some striking similarities in fluid inclusion data among sites. Most sites have an elevated temperature (100–300 °C), low salinity group of fluid inclusions within the NaCl–H$_2$O system, and a lower temperature (50–150 °C), higher salinity group of fluid inclusions within the NaCl–CaCl$_2$–H$_2$O system. Fluid inclusion density plots show some evidence of simple cooling, but most sites show two or more fluids were responsible for calcite formation. The origin of most of these fluids was magmatic/hydrothermal or meteoric water that had undergone varying degrees of water/rock interaction, but basinal brines and seawater were also possible sources. Several techniques and methods have been used to further characterize calcites. Strontium isotopes and rare earth elements can be useful to recognize different families of calcite. Uranium–Th dating has found many old calcites beyond the useful range of the technique, but also some relatively young calcites that may be related to interglacial periods. Where fluid inclusion data exists, formation temperatures were not consistent with a glacial water origin. Crush and leach experiments (with ion and gas chromatography and thermal ion mass spectrometry) have characterized inclusion fluids, but special care must be used to ensure only one generation is sampled at a time. Cathodoluminescence and scanning electron microscopy with energy-dispersive spectrometry has been useful in identifying multiple fluid generations within single calcite samples. Laser ablation and Raman spectrometry are additional techniques that are useful in determining individual fluid inclusion chemistry and isotopes.

10/00595 China needing a cautious approach to nuclear power strategy

Wang, Q. *Energy Policy*, 2009, 37, (7), 2487–2491.

China is leading the recent revival of nuclear energy programs. The Chinese government plans to increase nuclear generating capacity to 40 GWe by 2020, while the installed capacity is 8.6 GWe in 2007. In view of the enthusiasm shown for nuclear electricity throughout the country, the actual scale of Chinese nuclear power development is expected to reach 70 GWe by 2020. However, the low cost proven uranium reverses (cost category to <130 US$/kg) in China only meet half demand of 40 GWe capacity in 2020. And overlying China's increased demand is continued political sensitivity about the uranium trade. Meanwhile, the capacity of China's spent fuel reprocessing cannot keep up with the increasing spent fuel. And the legal administrative system of radioactive waste and spent fuel management is outdated. Hence it is proposed in this paper that the accelerated development of nuclear power industry is not good, and the over-accelerated development may be harmful, without appropriately considering the uranium resources and spent fuel management.

10/00596 Cost analysis of the US spent nuclear fuel reprocessing facility

Schneider, E. A. *et al. Energy Economics*, 2009, 31, (5), 627–634.

The US Department of Energy is actively seeking ways in which to delay or obviate the need for additional nuclear waste repositories beyond Yucca Mountain. All of the realistic approaches require the reprocessing of spent nuclear fuel. However, the USA currently lacks the infrastructure to do this and the costs of building and operating the required facilities are poorly established. Recent studies have also suggested that there is a financial advantage to delaying the deployment of such facilities. This study considers a system of government-owned reprocessing plants, each with a 40 year service life, that would reprocess spent nuclear fuel generated between 2010 and 2100. Using published data for the component costs, and a social discount rate appropriate for intergenerational analyses, the authors establish the unit cost for reprocessing and show that it increases slightly if deployment of infrastructure is delayed by a decade. The analysis indicates that achieving higher spent fuel discharge burnup is the most important pathway to reducing the overall cost of reprocessing. The analysis also suggests that a nuclear power production fee would be a way for the US government to recover the costs in a manner that is relatively insensitive to discount and nuclear power growth rates.

10/00597 Thermohydraulic transient studies of the Chinese 200 MWe HTR-PM for loss of forced cooling accidents

Zheng, Y. *et al. Annals of Nuclear Energy*, 2009, 36, (6), 742–751.

Pressurized and depressurized loss of forced cooling (PLOFC and DLOFC) are two important design basis accidents for high temperature gas-cooled reactors. Analysis of the reactor characteristic behaviours during LOFC can provide useful reference to the physics, thermohydraulic and structure designs of the reactor core, and can also verify the design of the residual heat removal system (RHRS). The 200 MWe high temperature gas-cooled reactor pebble-bed module project (HTR-PM), designed by the Institute of Nuclear and New

Energy Technology (INET) of Tsinghua University in China, is characterized by its inherent safety features, such as shutdown ability via negative temperature coefficients of reactivity, passive mechanism of decay heat removal and so on. In this paper, two cases of loss of forced cooling accidents have been analysed by using THERMIX code based on the preliminary design of the HTR-PM. With respect to the DLOFC, the effects of related key parameters on the maximum temperatures of fuel element and the reactor pressure vessel (RPV), as well as the decay heat removal by the RHRS are studied in detail. From the calculation results, it is shown that, in the LOFC accidents, the maximum temperatures of the fuel element and the RPV are below the safety limits and the RHRS can effectively remove the decay heat from the core, so as to keep the reactor in a safe state. As compared with the PLOFC accident, the DLOFC accident will lead to a much higher fuel element temperature but lower RPV temperatures and RHRS heat load. The analyses also illustrate that the decay heat level, the emissivity of RPV and water-cooling panel, and the average temperature of the water-cooling panel, play important roles in the DLOFC accident.

06 ELECTRICAL POWER SUPPLY AND UTILIZATION

Scientific, technical

10/00598 An analytical approach for assessment of voltage sags

Goswami, A. K. *et al. International Journal of Electrical Power & Energy Systems*, 2009, 31, (7–8), 418–426.

In this paper, analytical expressions for the calculation of remaining voltages due to fault at bus and along the line are derived. Balanced and unbalanced faults are considered and the effects of different fault distributions are taken into account. The proposed analytical methods are compared with the method of critical distance in order to achieve the acceptability of the proposed method. The developed method is applied to the IEEE 30-bus test system and a real Indian distribution system.

10/00599 An efficient hybrid evolutionary algorithm based on PSO and HBMO algorithms for multi-objective Distribution Feeder Reconfiguration

Niknam, T. *Energy Conversion and Management*, 2009, 50, (8), 2074–2082.

This paper introduces a robust searching hybrid evolutionary algorithm to solve the multi-objective distribution feeder reconfiguration (DFR). The main objective of the DFR is to minimize the real power loss, deviation of the nodes' voltage, the number of switching operations, and balance the loads on the feeders. Because of the fact that the objectives are different and no commensurable, it is difficult to solve the problem by conventional approaches that may optimize a single objective. This paper presents a new approach based on norm3 for the DFR problem. In the proposed method, the objective functions are considered as a vector and the aim is to maximize the distance (norm2) between the objective function vector and the worst objective function vector while the constraints are met. Since the proposed DFR is a multi objective and non-differentiable optimization problem, a new hybrid evolutionary algorithm (EA) based on the combination of the honey bee mating optimization (HBMO) and the discrete particle swarm optimization (DPSO), called DPSO–HBMO, is implied to solve it. The results of the proposed reconfiguration method are compared with the solutions obtained by other approaches, the original DPSO and HBMO over different distribution test systems.

10/00600 An integrated DEA–COLS–SFA algorithm for optimization and policy making of electricity distribution units

Azadeh, A. *et al. Energy Policy*, 2009, 37, (7), 2605–2618.

This paper presents an integrated data envelopment analysis (DEA)–corrected ordinary least squares (COLS)–stochastic frontier analysis (SFA)–principal component analysis (PCA)–numerical taxonomy (NT) algorithm for performance assessment, optimization and policy making of electricity distribution units. Previous studies have generally used input–output DEA models for benchmarking and evaluation of electricity distribution units. However, this study proposes an integrated flexible approach to measure the rank and choose the best version of the DEA method for optimization and policy-making purposes. It covers both static and dynamic aspects of information environment due to involvement of SFA, which is finally compared with the best DEA model through the Spearman correlation technique. The integrated approach would yield in improved ranking and optimization of electricity distribution systems. To illustrate the usability and reliability of the proposed algorithm, 38 electricity distribution units in Iran have been considered, ranked and optimized by the proposed algorithm of this study.

10/00601 Cogeneration systems with electric heat pumps: energy-shifting properties and equivalent plant modelling

Mancarella, P. *Energy Conversion and Management*, 2009, 50, (8), 1991–1999.

In this paper, a novel approach to energy and CO_2 emission modelling of cogeneration systems coupled to electric heat pumps is presented. The specific objectives are to identify the relevant parameters and variables involved in the analysis of such composite systems, and to provide a synthetic and indicative assessment of the energy and environmental benefits potentially brought with respect to conventional energy systems. To this purpose, the concept of equivalent cogeneration plant is introduced, characterized by equivalent electrical and thermal efficiencies obtained by transforming the classical cogeneration efficiencies through the energy-shifting characteristics of the heat pump. The latter point is further highlighted by introducing equivalent cogeneration ratios and a thermal multiplication factor (TMF) indicator. This formulation allows investigation of the performance of the cogeneration-heat pump system by using the equivalent efficiencies as the input entries to equivalent energy saving and emission reduction indicators. The conditions at which energy and emission benefits occur, and their extent with respect to classical generation means, are illustrated through various numerical examples, highlighting the generality and effectiveness of the models introduced. In particular, equivalent cogeneration systems for small-scale distributed applications can exhibit energy saving and emission reduction of the order of up to 50% with respect to benchmark generation means within a typical Italian energy context.

10/00602 Design of a nonlinear power system stabilizer using synergetic control theory

Jiang, Z. *Electric Power Systems Research*, 2009, 79, (6), 855–862.

Electromechanical oscillations of small magnitude and low frequency exist in the interconnected power system and often persist for long periods of time. Power system stabilizers (PSSs) are traditionally used to provide damping torque for the synchronous generators to suppress the oscillations by generating supplementary control signals for the generator excitation system. Numerous techniques have previously been proposed to design PSSs but many of them are synthesized based on a linearized model. This paper presents a non-linear power system stabilizer based on synergetic control theory. Synergetic synthesis of the PSS is based fully on a simplified non-linear model of the power system. The dynamic characteristics of the proposed PSS are studied in a typical single-machine infinite-bus power system and compared with the cases with a conventional PSS and without a PSS. Simulation results show the proposed PSS is robust for such non-linear dynamic system and achieves better performance than the conventional PSS in damping oscillations.

10/00603 Domestic lighting: a high-resolution energy demand model

Richardson, I. *et al. Energy and Buildings*, 2009, 41, (7), 781–789.

The use of electric lighting in the domestic sector depends mainly on the level of natural light coming in from outdoors, coupled with the activity of the household residents. This paper presents a detailed model of domestic lighting use that takes these two factors as its basic inputs. The operation of individual bulbs is represented within the model and is used to construct high-resolution lighting electricity demand profiles for individual dwellings. The model is computationally efficient and can easily provide data at 1-min resolution for a large numbers of dwellings. As a primary input, the model uses a time-series representing the number of active occupants within a dwelling (people who are at home and awake). This allows it to represent the sharing of lighting between the occupants of a given dwelling and facilitates correlated linking to models of other energy use within the dwelling. Appropriate correlation between dwellings is achieved through the use of appropriate active occupancy data and outdoor ambient light data. An example implementation of the model in Microsoft Excel is available.

10/00604 Estimate of the electric energy generating potential for different sources of biogas in Brazil

Salomon, K. R. *et al. Biomass and Bioenergy*, 2009, 33, (9), 1101–1107.

The increasing interest in the recuperation of the biogas coming from organic residues, associated with its energetic use is a subject that has been widely discussed. Biogas was merely seen as a sub-product obtained from anaerobic decomposition (without oxygen) of organic residue. In the paper is carried out an evaluation of the quantities of organic residues coming out from the sugar and alcohol industry (vinasse), urban solid and liquid wastes (garbage and sewage) and livestock residues (bovine and swine manure) in Brazil. Finally the electricity generation potential of biogas out of the evaluated sources of organic residues in Brazil is estimated. The results of this study indicate that the potential regarding the production of biogas out of the aforementioned organic residues of electricity production using could meet an energy demand of about 1.05 to 1.13%. Constraints for biogas energy utilization are identified and discussed.

10/00605 High-performance sensorless nonlinear power control of a flywheel energy storage system

Amodeo, S. J. *et al. Energy Conversion and Management*, 2009, 50, (7), 1722–1729.

The flywheel energy storage systems (FESS) can be used to store and release energy in high power pulsed systems. Based on the use of a homopolar synchronous machine in a FESS, a high performance model-based power flow control law is developed using the feedback linearization methodology. This law is based on the voltage space vector reference frame machine model. To reduce the magnetic losses, a pulse amplitude modulation driver for the armature is more adequate. The restrictions in amplitude and phase imposed by the driver are also included. A full-order Luenberger observer for the torque angle and rotor speed is developed to implement a sensorless control strategy. Simulation results are presented to illustrate the performance.

10/00606 k-means algorithm and mixture distributions for locating faults in power systems

Mora-Flórez, J. *et al. Electric Power Systems Research*, 2009, 79, (5), 714–721.

Enhancement of power distribution system reliability requires of a considerable investment in studies and equipment, however, not all the utilities have the capability to spend time and money to assume it. Therefore, any strategy that allows the improvement of reliability should be reflected directly in the reduction of the duration and frequency interruption indexes (SAIFI and SAIDI). In this paper, an alternative solution to the problem of power service continuity associated to fault location is presented. A methodology of statistical nature based on finite mixtures is proposed. A statistical model is obtained from the extraction of the magnitude of the voltage sag registered during a fault event, along with the network parameters and topology. The objective is to offer an economic alternative of easy implementation for the development of strategies oriented to improve the reliability from the reduction of the restoration times in power distribution systems. In the application case for an application example in a power distribution system, the faulted zones were identified, having low error rates.

10/00607 Measurement of a power system nominal voltage, frequency and voltage flicker parameters

Alkandari, A. M. and Soliman, S. A. *International Journal of Electrical Power & Energy Systems*, 2009, 31, (7–8), 295–301.

This paper presents an approach for identifying the frequency and amplitude of voltage flicker signal that imposed on the nominal voltage signal, as well as the amplitude and frequency of the nominal signal itself. The proposed algorithm performs the estimation in two steps; in the first step the original voltage signal is shifted forward and backward by an integer number of sample, one sample in this paper. The new generated signals from such a shift together with the original one is used to estimate the amplitude of the original signal voltage that composed of the nominal voltage and flicker voltage. The average of this amplitude gives the amplitude of the nominal voltage; this amplitude is subtracted from the original identified signal amplitude to obtain the samples of the flicker voltage. In the second step, the argument of the signal is calculated by simply dividing the magnitude of signal sample with the estimated amplitude in the first step. Calculating the arccosine of the argument, the frequency of the nominal signal as well as the phase angle can be computing using the least error square estimation algorithm. Simulation examples are given within the text to show the features of the proposed approach.

10/00608 On feasibility of regional frequency-based emergency control plans

Bevrani, H. *et al. Energy Conversion and Management*, 2009, 50, (7), 1656–1663.

Decentralized and regional load-frequency control of power systems operating in normal and near-normal conditions has been well studied; and several analysis/synthesis approaches have been developed during the last few decades. However in contingency and off-normal conditions, the existing emergency control plans, such as under-frequency load shedding, are usually applied in a centralized structure using a different analysis model. This paper discusses the feasibility of using frequency-based emergency control schemes based on tie-line measurements and local information available within a control area. The conventional load-frequency control model is generalized by considering the dynamics of emergency control/protection schemes and an analytic approach to analyse the regional frequency response under normal and emergency conditions is presented.

10/00609 Online fuzzy voltage collapse risk quantification

Berizzi, A. *et al. Electric Power Systems Research*, 2009, 79, (5), 740–749.

Many voltage stability indicators have been proposed in the past for the voltage collapse assessment. Almost all of them are determined through quite complex analytical tools; therefore, it is difficult for system operators to give them a physical meaning. In order to perform a simple and reliable evaluation of the security margins, it is necessary to make a synthesis of the information given by the various indices. The present work proposes an artificial intelligence-based tool for the evaluation of the voltage security. In particular, a fuzzy inference engine is developed and optimized by two different approaches (neural networks and genetic algorithms). Starting from the state estimation, a given set of mathematical indices is computed to represent a snapshot of the current electric system operating point. The numerical values are then translated into a set of symbolic and linguistic quantities that are manipulated through a set of logical connectives and inference methods provided by the mathematical logic. As a result, the fuzzy logic gives a MW measure of the distance from the collapse limit, a metric usually appreciated by system operators. The fuzzy system has been built and optimized by using, as a test system, a detailed model of the EHV Italian transmission network connected to an equivalent of the UCTE network (about 1700 buses).

10/00610 Optimal interval for major maintenance actions in electricity distribution networks

Louit, D. *et al. International Journal of Electrical Power & Energy Systems*, 2009, 31, (7–8), 396–401.

Many systems require the periodic undertaking of major (preventive) maintenance actions (MMAs) such as overhauls in mechanical equipment, reconditioning of train lines, resurfacing of roads, etc. In the long term, these actions contribute to achieving a lower rate of occurrence of failures, though in many cases they increase the intensity of the failure process shortly after performed, resulting in a non-monotonic trend for failure intensity. Also, in the special case of distributed assets such as communications and energy networks, pipelines, etc., it is likely that the maintenance action takes place sequentially over an extended period of time, implying that different sections of the network underwent the MMAs at different periods. This forces the development of a model based on a relative time scale (i.e. time since last major maintenance event) and the combination of data from different sections of a grid, under a normalization scheme. Additionally, extended maintenance times and sequential execution of the MMAs make it difficult to identify failures occurring before and after the preventive maintenance action. This results in the loss of important information for the characterization of the failure process. A simple model is introduced to determine the optimal MMA interval considering such restrictions. Furthermore, a case study illustrates the optimal tree trimming interval around an electricity distribution network.

10/00611 Performance evaluation of a tri-generation system with simulation and experiment

Ge, Y. T. *et al. Applied Energy*, 2009, 86, (11), 2317–2326.

A test rig for a tri-generation system was set up in the laboratory to investigate the system performance and application feasibility. The rig was composed of three modules, a power component containing a microturbine, a refrigeration unit consisting of an absorption chiller with gas pipe connection, and a supermarket section containing a display cabinet. This system was supposed to be effectively applied into a supermarket energy control system where cooling, heating and electricity power are simultaneously required and subsequently, valuable test results have been produced. In the mean time, a simulation model for the particular tri-generation system has been established by integrating the component models of the system in accordance with the components' actual flow paths and energy streams. These component models, which include a compressor, recuperator, combustion chamber, gas turbine, electric generator, gas pipes, generator (desorber), rectifier, absorbers, condenser and evaporator, etc., were developed based upon the balance of heat and mass. The calculations of heat transfer and phase equilibrium were included in the component models and chemical reaction balances were considered in the model of the combustion chamber. The system model has been validated with the test results and has consequently been used to predict the system performance at different operating and design conditions, such as varied ambient temperature, fuel flow rate and pressure ratio, etc. The ultimate results of the performance analysis formulated by the system model can contribute significantly to the optimal component and system designs in various practical applications.

10/00612 Regional frequency response analysis under normal and emergency conditions

Bevrani, H. *et al. Electric Power Systems Research*, 2009, 79, (5), 837–845.

This paper presents a frequency response analysis approach suitable for a power system control area in a wide range of operating conditions. The analytic approach uses the well-known system frequency response model for the turbine–governor and load units to obtain the mathematical representation of the basic concepts. Primary and supplementary frequency controls are properly considered and the effect of emergency control/protection schemes is included. Therefore, the proposed analysis/modelling approach could be gainfully used for the power system operation during the contingency and normal conditions. Time-domain non-linear simulations with a power system example showed that the results agree with those predicted analytically.

10/00613 The value of reducing distribution losses by domestic load-shifting: a network perspective

Shaw, R. *et al. Energy Policy*, 2009, 37, (8), 3159–3167.

Shifting domestic load to off-peak time periods could potentially reduce electrical distribution losses and associated carbon emissions. This paper provides the first quantitative estimate of the possible reduction in losses, for a situation where domestic energy demand is shifted in time but not reduced. At a likely 0.02% of energy distributed by the network, the reduction is small relative to overall losses and to their variability, giving little rationale for distribution network operators in Great Britain to encourage such load-shifting for that reason. The paper also considers the limited regulatory incentives for the reduction, and the fragmentation of costs and benefits across different parties. The societal value is considerably higher than the current regulatory incentive, but nonetheless may still not warrant the cost of action. Reducing rather than shifting load is likely to give greater environmental benefits.

10/00614 Wavelet transform based digital protection for transmission lines

Valsan, S. P. and Swarup, K. S. *International Journal of Electrical Power & Energy Systems*, 2009, 31, (7–8), 379–388.

This paper presents a high speed, computationally efficient scheme for protection of transmission lines. The relay logic consists of three parts: directional protection, fault classification and fault location. Wavelet transform is used for extracting information from the fault transients and only the first level high frequency details of the voltages and currents are used. Proposed protection logic compares the directional signals from both terminals to discriminate between faults inside and outside the zone of interest. Fault classification is achieved using local terminal current information. An estimate of the location of the faults is obtained utilizing single faulted phase current information from both terminals. The logic is deterministic and can work reliably in the presence of fault resistance, load variation and CT saturation. The validity of the proposed logic was exhaustively tested by simulating various types of faults on a four bus meshed system modelled in EMTP/ATP.

Economics, policy, supplies, forecasts

10/00615 A dynamic replicator model of the players' bids in an oligopolistic electricity market

Sahraei-Ardakani, M. and Rahimi-Kian, A. *Electric Power Systems Research*, 2009, 79, (5), 781–788.

In this paper, the replicator dynamics of the power suppliers' bids in an oligopolistic electricity market are derived for both the fixed and variable demand cases. The replicator dynamics stability analysis is also performed. The dynamics of the electricity markets are the results of players' decisions. The physical parameters of the power systems (such as the lines capacities, voltage limitations, etc.) also affect the market dynamics indirectly, through the changes in players' behaviours. Assuming rational players, an optimal bidding strategy for constructing the supply function (SF) of a generating firm is presented and based on that, the dynamics of the bid replicators are studied. Both fixed demands and price sensitive demands are taken into account. The replicator model is presented in the well-known state space structure. A case study is presented to show the applicability of the developed dynamic replicator bid model, and also to show how the Nash–SFE equilibrium evolves over time.

10/00616 A new decoupling strategy for power system state estimation

Neela, R. and Aravindhababu, P. *Energy Conversion and Management*, 2009, 50, (8), 2047–2051.

This paper presents a new decoupling strategy by strengthening P–δ and Q–V relationships based on line flow and voltage magnitude measurements in order to obtain a reliable convergence and higher computational speed. The real and reactive set of measurements are combined using simple multiplying factors such that the modified set is decoupled into two set of equations without making any assumption on r/x ratios. The resulting Jacobian matrices that contain only line parameters are sparse and constant. The technique is applied on three test systems and is solved by WLS and WLAV methods to illustrate its superior performance.

10/00617 An assessment of the effectiveness of fuel cycle technologies for the national energy security enhancement in the electricity sector

Kim, H. Y. *et al. Annals of Nuclear Energy*, 2009, 36, (5), 604–611.

Energy security, in the twenty-first century, draws significant attention in most countries worldwide, because the national security and sustainable development depend largely on energy security. The anticipated fossil energy depletion and the instability of their supply drive many countries to consider nuclear energy as their alternative energy source for the enhancement of their national energy security. In this study, indicators measuring the level of energy security in the electric power sector are developed and applied for the assessment of the effectiveness of four electric power system schemes which deploy different nuclear fuel cycle technologies, with consideration for the diversification of the energy markets and the vulnerability to economic disruption. Results show that the contribution of the closed fuel cycle scheme is larger than the once-through fuel cycle scheme in the perspective of energy security. In addition, the completely closed fuel cycle with the spent fuel recycling enhances the national energy security to the maximum extent compared to all other fuel cycle schemes. Since a completely closed fuel cycle is hardly affected by the uranium price changes, this scheme is found to be the most favourable scheme, ensuring the stable profit of utilities and stabilizing the electricity tariff. In addition, the completely closed fuel cycle scheme provides the best enhancement of national energy security with respect to energy supply, under reasonable price conditions. The indicators developed in this study can be utilized as a useful instrument for the measurement of the level of the energy security, especially by the countries importing energy resources for the generation of electric power.

10/00618 An overview on network cost allocation methods

Lima, D. A. *et al. Electric Power Systems Research*, 2009, 79, (5), 750–758.

This work is devoted to study and discuss the main methods to solve the network cost allocation problem both for generators and demands. From the presented, compared and discussed methods, the first one is based on power injections, the second deals with proportional sharing factors, the third is based upon equivalent bilateral exchanges, the fourth analyses the power flow sensitivity in relation to the power injected, and the last one is based on Z_{bus} network matrix. All the methods are initially illustrated using a 4-bus system. In addition, the IEEE 24-bus RTS system is presented for further comparisons and analysis. Appropriate conclusions are finally drawn.

10/00619 Analytical model for unavailability due to aging failures in power systems

Xie, K. G. and Li, W. Y. *International Journal of Electrical Power & Energy Systems*, 2009, 31, (7–8), 345–350.

Power system component failures can generally be classified into two categories: repairable random failures and ageing failures. An essential step in power system reliability evaluation is the calculation of component unavailability. The paper presents a new model for calculating the unavailability due to ageing failures using the normal distribution. It is based on the strictly mathematical derivation and can be used more easily with high accuracy compared to the traditional model. An example of seven generating units and two test systems of the RBTS and the IEEE-RTS were used to demonstrate effectiveness of the proposed model and its applications in power system reliability evaluation.

10/00620 Applying a non-intrusive energy-management system to economic dispatch for a cogeneration system and power utility

Chang, H. and Yang, H. *Applied Energy*, 2009, 86, (11), 2335–2343.

Non-intrusive energy-management (NIEM) techniques are based on energy signatures. While such approaches lack transient energy signatures, the reliability and accuracy of recognition results cannot be determined. By using neural networks (NNs) in combination with turn-on transient energy analysis, this study attempts to identify load demands and improve recognition accuracy of NIEM results. Case studies are presented that apply various methods to compare training algorithms and classifiers in terms of artificial neural networks due to various factors that determine whether a network is being used for pattern recognition. Additionally, in combination with electromagnetic transient program simulations, calculating the turn-on transient energy facilitate load can lead to identification and a significant improvement in the accuracy of NIEM results. Analysis results indicate that an NIEM system can effectively manage energy demands within economic dispatch for a cogeneration system and power utility. Additionally, a new method based on genetic algorithms is used to develop a novel operational strategy of economic dispatch for a cogeneration system in a regulated market and approach the global optimum with typical environmental constraints for a cogeneration plant. Economic dispatch results indicate that the NIEM system based on energy demands can estimate accurately the energy contribution from the cogeneration system and power utility, and further reduce air pollution. Moreover, applying the NIEM system for economic dispatch can markedly reduce computational time and power costs.

10/00621 Comparison of metaheuristic techniques to determine optimal placement of biomass power plants

Reche-López, P. *et al. Energy Conversion and Management*, 2009, 50, (8), 2020–2028.

This paper deals with the application and comparison of several metaheuristic techniques to optimize the placement and supply area of biomass-fuelled power plants. Both, trajectory and population-based methods are applied. In particular, two well-known trajectory methods, such as simulated annealing (SA) and tabu search (TS), and two commonly used population-based methods, such as genetic algorithms (GA) and particle swarm optimization (PSO) are hereby considered. In addition, a new binary PSO algorithm has been proposed, which incorporates an inertia weight factor, like the classical continuous approach. The fitness function for the metaheuristics is the profitability index, defined as the ratio between the net present value and the initial investment. In this work, forest residues are considered as biomass source, and the problem constraints are: the generation system must be located inside the supply area, and its maximum electric power is 5 MW. The comparative results obtained by all considered metaheuristics are discussed. Random walk has also been assessed for this problem.

10/00622 Constructing load profiles for household electricity and hot water from time-use data – modelling approach and validation

Widén, J. *et al. Energy and Buildings*, 2009, 41, (7), 753–768.

Time-use data, describing in detail the everyday life of household members as high-resolved activity sequences, have a largely unrealized potential of contributing to domestic energy demand modelling. A model for computation of daily electricity and hot-water demand profiles from time-use data was developed, using simple conversion schemes, mean appliance and water-tap data and general daylight availability distributions. Validation against detailed, end-use specific electricity measurements in a small sample of households reveals that the model for household electricity reproduces hourly load patterns with preservation of important qualitative features. The output from the model, when applied to a large data set of time use in Sweden, also shows correspondence to aggregate profiles for both household electricity and hot water from recent Swedish measurement surveys. Deviations on individual household level are predominantly due to occasionally ill-reported time-use data and on aggregate population level due to slightly non-representative samples. Future uses and developments are identified and it is suggested that modelling energy use from time-use data could be an alternative, or a complement, to energy demand measurements in households.

10/00623 DCGA based evaluating role of bundle lines in TNEP considering expansion of substations from voltage level point of view

Mahdavi, M. *et al. Energy Conversion and Management*, 2009, 50, (8), 2067–2073.

Transmission network expansion planning (TNEP) is an important component of power system planning. It determines the characteristic and performance of the future electric power network and influences the power system operation directly. Up until now, various methods have been presented for the solution of static TNEP (STNEP) problem. However, in all of them, the role of bundle lines in TNEP problem considering the expansion of substations from the voltage level point of view has not been investigated. Thus, in this paper, the role of bundle lines in STNEP problem is being studied considering expansion cost of substations from the voltage level point of view using decimal codification genetic algorithm (DCGA). The effectiveness of the proposed idea is tested on an actual transmission network of the Azerbaijan regional electric company, Iran. The results reveal that bundle lines have effective role in transmission expansion planning and subsequent determining the network arrangement. In addition, considering the bundle lines in a power system is caused that the expansion cost of lines and substations decreases and therefore the total expansion cost of network is minimized. Also, it can be said, although cost of bundle lines are more than those which have not bundle conductor, constructing this type of lines in a transmission network with different voltage levels prevents useless expansion of unbundled lines in separate corridors and therefore the network expansion planning is optimized.

10/00624 Electricity consumption and economic growth in South Africa: a trivariate causality test

Odhiambo, N. M. *Energy Economics*, 2009, 31, (5), 635–640.

This paper examines the causal relationship between electricity consumption and economic growth in South Africa. The authors incorporate the employment rate as an intermittent variable in the bivariate model between electricity consumption and economic growth – thereby creating a simple trivariate causality framework. The empirical results show that there is a distinct bidirectional causality between electricity consumption and economic growth in South Africa. In addition, the results show that employment in South Africa Granger-causes economic growth. The results apply irrespective of whether the causality is estimated in the short-run or in the long-run formulation. The study, therefore, recommends that policies geared towards the expansion of the electricity infrastructure should be intensified in South Africa in order to cope with the increasing demand exerted by the country's strong economic growth and rapid industrialization programme. This will certainly enable the country to avoid unprecedented power outages similar to those experienced in the country in mid-January 2008.

10/00625 Feasibility of CHP-plants with thermal stores in the German spot market

Streckiene, G. *et al. Applied Energy*, 2009, 86, (11), 2308–2316.

The European Energy Exchange (EEX) day ahead spot market for electricity in Germany shows significant variations in prices between peak and off-peak hours. Being able to shift electricity production from off-peak hours to peak hours improves the profit from CHP-plant operation significantly. Installing a big thermal store at a CHP-plant makes it possible to shift production of electricity and heat to hours where electricity prices are highest especially on days with low heat demand. Consequently, these conditions will have to influence the design of new CHP-plants. In this paper, the optimal size of a CHP-plant with thermal store under German spot market conditions is analysed. As an example the possibility to install small size CHP-plant instead of only boilers at a Stadtwerke delivering 30,000 MW h-heat for district heating per year is examined using the software energyPRO. It is shown that, given the economic and technical assumptions made, a CHP-plant of 4 MW-el with a thermal store participating in the spot market will be the most feasible plant to build. A sensitivity analysis shows to which extent the optimal solution will vary by changing the key economic assumptions.

10/00626 Frequency domain methods applied to forecasting electricity markets

Trapero, J. R. and Pedregal, D. J. *Energy Economics*, 2009, 31, (5), 727–735.

The changes taking place in electricity markets during the last two decades have produced an increased interest in the problem of forecasting, either load demand or prices. Many forecasting methodologies are available in the literature nowadays with mixed conclusions about which method is most convenient. This paper focuses on the modelling of electricity market time series sampled hourly in order to produce short-term (1 to 24 h ahead) forecasts. The main features of the system are that (i) models are of an unobserved component class that allow for signal extraction of trend, diurnal, weekly and irregular components; (ii) its application is automatic, in the sense that there is no need for human intervention via any sort of identification stage; (iii) the models are estimated in the frequency domain; and (iv) the robustness of the method makes possible its direct use on both load demand and price time series. The approach is thoroughly tested on the PJM interconnection market and the results improve on classical ARIMA models.

10/00627 Hybrid evolutionary algorithms in a SVR-based electric load forecasting model

Hong, W.-C. *International Journal of Electrical Power & Energy Systems*, 2009, 31, (7–8), 409–417.

Accurately electric load forecasting has become the most important issue in energy management; however, electric load often presents non-linear data patterns. Therefore, looking for a novel forecasting approach with strong general non-linear mapping capabilities is essential. Support vector regression (SVR) reveals superior non-linear modelling capabilities by applying the structural risk minimization principle to minimize an upper bound of the generalization errors, it is quite different with ANNs model that minimizing the training errors. The purpose of this paper is to present a SVR model with a hybrid evolutionary algorithm (chaotic genetic algorithm, CGA) to forecast the electric loads, CGA is applied to the parameter determine of SVR model. With the increase of the complexity and the larger problem scale of electric loads, genetic algorithms (GAs) are often faced with the problems of premature convergence, slowly reaching the global optimal solution or trapping into a local optimum. The proposed CGA based on the chaos optimization algorithm and GAs, which employs internal randomness of chaos iterations, is used to overcome premature local optimum in determining three parameters of a SVR model. The empirical results indicate that the SVR model with CGA (SVRCGA) results in better forecasting performance than the other methods, namely SVMG (SVM model with GAs), regression model, and ANN model.

10/00628 Influencing households' energy behaviour – how is this done and on what premises?

Gyberg, P. and Palm, J. *Energy Policy*, 2009, 37, (7), 2807–2813.

This article examines the discourse that the idea of efficiency is built upon according to different actors trying to influence households' energy behaviour in Sweden. The focus is on information from authorities as well as from interest organizations and energy companies. Information directed to households often contains a strong idea that the individuals have to take responsibility for their own choices, and that it is through consumer choices the energy system will become more sustainable. The reasons given for changing one's behaviour are motivated both by lower energy costs and a reduced impact on the environment. Common advice for energy reduction is to change to a more energy-efficient apparatus. In this sense efficiency is a way of not changing lifestyle but instead changing technical equipment and user routines. Only the LA21 project questions the need for all the apparatus as well as the possibility to improve existing artifacts, pointing to a need to change our lifestyle. The strong belief in science and technology results in a definition of the problem as a lack of knowledge, where the only solution is to fill this gap.

10/00629 Market data analysis and short-term price forecasting in the Iran electricity market with pay-as-bid payment mechanism

Bigdeli, N. *et al. Electric Power Systems Research*, 2009, 79, (6), 888–898.

The data analysis procedure includes both correlation and predictability analysis of the most important load and price indices. The employed data are the experimental time series from Iran electricity market in its real size and is long enough to make it possible to take properties such as non-stationarity of market into account. For predictability analysis, the bifurcation diagrams and recurrence plots of the data have been investigated. The results of these analyses indicate existence of deterministic chaos in addition to non-stationarity property of the system which implies short-term predictability. In the next step, two artificial neural networks have been developed for forecasting the two price indices in Iran's electricity market. The models' input sets are selected regarding four aspects: the correlation properties of the available data, the critiques of Iran's electricity market, a proper convergence rate in case of sudden variations in the market price behaviour, and the omission of cumulative forecasting errors. The simulation results based on experimental data from Iran electricity market are representative of good performance of the developed neural networks in coping with and forecasting of the market behaviour, even in the case of severe volatility in the market price indices.

10/00630 Permit markets, market power, and the trade-off between efficiency and revenue raising

Antelo, M. and Bru, L. *Resource and Energy Economics*, 2009, 31, (4), 320–333.

This paper focuses on an emissions permit market dominated by one firm and with a government concerned about social efficiency and permits revenue. In this setting, it is shown that the dominant firm's market power reduces the opportunities for the government to raise non-distortionary revenue from permits without loss of consumer surplus. Since the government's objectives are thus hampered in auctioning permits, the dominant firm should be excluded from the auction. Specifically, the regulator should sell permits directly, through bilateral negotiation, to the dominant firm, and auction off the remaining permits to the fringe firms.

10/00631 Productivity growth and deregulation of Japanese electricity distribution

Goto, M. and Sueyoshi, T. *Energy Policy*, 2009, 37, (8), 3130–3138.

Deregulation of Japanese electric power industry began in 1995. After the amendment of Electricity Utility Industry Law in 1995, competition was partially introduced in a generation sector and retail competition started from 2000. Eligibility to choose suppliers was gradually extended from larger to smaller customers. As of 2008, almost all customers except households can choose their electricity suppliers. Based upon both previous implementation result of competition policy and review on their achievement, the Japanese government will begin a new policy debate in 2013 to assess further retail competition which includes household customers. To prepare for policy suggestion on the future electric power industry, this study examines the cost structure of Japanese electricity distribution. For the purpose, the authors estimate a multi-product translog cost function of Japanese electricity distribution from 1983 to 2003. Using the estimated cost function, several economic measures are calculated, such as productivity growth, technical change and economies of scale and scope. The empirical results of this study indicate the improvement in productivity growth after deregulation.

10/00632 Studies of air-flow and temperature fields inside a passenger compartment for improving thermal comfort and saving energy. Part I: Test/numerical model and validation

Zhang, H. *et al. Applied Thermal Engineering*, 2009, 29, (10), 2022–2027.

It is important to analyse the temperature and air-flow field inside the passenger compartment to ameliorate the amenity and decrease energy consumption. This paper uses commercial software, FLUENT, to simulate 3-D temperature distributions and flow field in a compartment with or without passengers. Validated by the experimental data, the numerical model is used to investigate the influence of different factors on the thermal comfort and the energy consumption. In the first paper, the test conditions and the numerical models are described in details. The measured and predicted transient temperatures are compared and good agreement is obtained. In addition, the air temperature distribution in a steady test situation is also numerically predicted by both transient and steady model, and the agreements between the three sets of data are satisfactorily, showing the reliability of the models. In the companion part of the two papers the simulated effects of several operational conditions will be presented.

10/00633 Studies of air-flow and temperature fields inside a passenger compartment for improving thermal comfort and saving energy. Part II: Simulation results and discussion

Zhang, H. *et al. Applied Thermal Engineering*, 2009, 29, (10), 2028–2036.

In the first paper the simulation model, numerical methods and experimental measurement validation for a vehicle compartment with two chairs and one long bench have been provided. In this paper, the simulated results are presented. Simulation results with a variety of conditions reveal that: (1) a good choice for decreasing the cooling load in the summer time is increasing the inlet air temperature, not reducing the volume flow rate of the inlet air; (2) the thermal comfort in a compartment with given conditions depends on the number of persons in it. For the compartment studied, when there are two passengers in the compartment both of them should sit in the backside; (3) the outside temperature has appreciable effect on the cooling load. While change of the vehicle speed hardly affects the cooling load of air conditioner when good seal of the compartment is assumed; (4) to decrease the cooling load one can change the material of the window (reducing its transmissivity), and improve thermal insulation on the vehicle body; (5) a better flow circulation near the compartment bottom is favourable to improve the uniformity of temperature field around the driver's foot zone. The inlet air direction should be kept horizontal.

10/00634 Study of multi-objective optimization and multi-attribute decision-making for economic and environmental power dispatch

Li, X. *Electric Power Systems Research*, 2009, 79, (5), 789–795.

Environmental awareness and the recent environmental policies have forced many electric utilities to restructure their practices to account for their emission impacts. One way to accomplish this is by reformulating the traditional economic dispatch problem such that emission effects are included in the mathematical model. The economic/environmental dispatch problem is a multi-objective nonlinear optimization problem with constraints. This study presents a hybrid approach to solve the combined economic-emission dispatch problem (CEED). In the first stage, a non-dominated sorting genetic algorithm II (NSGA II) is employed to approximate the set of Pareto solution through an evolutionary optimization process. In the subsequent stage, a multi-attribute decision-making (MADM) approach is adopted to rank these solutions from best to worst and to determinate the best solution in a deterministic environment with a single decision maker. This hybrid approach is tested on a six-unit system to illustrate the analysis process in present analysis. Pareto frontiers are obtained and the ranking of Pareto solutions is based on entropy weight and TOPSIS method. Results obtained show that the hybrid approach has a great potential in handling multi-objective optimization problem.

10/00635 The impact of microgeneration upon the Dutch balancing market

Van der Veen, R. A. C. and De Vries, L. J. *Energy Policy*, 2009, 37, (7), 2788–2797.

The share of microgeneration (power generation at the level of households and small businesses) in the Dutch electricity system continues to grow. Over time, this development may pose a threat to the reliability and efficiency of the Dutch electricity balancing market. This study investigated possible changes to the design of the Dutch balancing market that can maintain or even improve upon its current operational performance level. The first step of the research was an analysis of the existing Dutch balancing market. It consists of three main instruments: programme responsibility, the single buyer market for regulating and reserve power (RRP), and imbalance settlement. The balancing market currently functions satisfactorily. Subsequently, the effects of large-scale development of microgeneration in the Netherlands were evaluated with a qualitative scenario analysis. Four microgeneration scenarios and two methods for allocating the household electricity consumption and generation were considered. The four scenarios concerned large-scale penetration of PV, heat-led micro CHP, electricity-led micro CHP operated by the household consumer, and electricity-led micro CHP operated by the supply company. The last scenario was found to have the strongest positive net effect. Finally, six design options were identified for improving the Dutch balancing market design in case the share of microgeneration would increase substantially. Of these six options, adjusting the profile methodology and the regulation of smart meters are no-regret options that can be implemented immediately. The attractiveness of the other options depends upon the microgeneration portfolio that emerges, the manageability of large metering data flows, and the nature of the technical effects of large-scale microgeneration penetration.

10/00636 The value of compressed air energy storage with wind in transmission-constrained electric power systems

Denholm, P. and Sioshansi, R. *Energy Policy*, 2009, 37, (8), 3149–3158.

This study examines the potential advantages of co-locating wind and energy storage to increase transmission utilization and decrease transmission costs. Co-location of wind and storage decreases transmission requirements, but also decreases the economic value of energy storage compared to locating energy storage at the load. This represents a tradeoff which the authors examine to estimate the transmission costs required to justify moving storage from load-sited to wind-sited in three different locations in the United States. Compressed air energy storage (CAES) was examined in three 'wind by wire' scenarios with a variety of transmission and CAES sizes relative to a given amount of wind. In the sites and years evaluated, the optimal amount of transmission ranges from 60% to 100% of the wind farm rating, with the optimal amount of CAES equal to 0–35% of the wind farm rating, depending heavily on wind resource, value of electricity in the local market, and the cost of natural gas.

10/00637 Transmission usage cost allocation schemes

Abou El Ela, A. A. and El-Sehiemy, R. A. *Electric Power Systems Research*, 2009, 79, (6), 926–936.

This paper presents different suggested transmission usage cost allocation (TCA) schemes to the system individuals. Different independent system operator (ISO) visions are presented using the proportional rata and flow-based TCA methods. There are two proposed flow-based TCA schemes (FTCA). The first FTCA scheme generalizes the equivalent bilateral exchanges concepts for lossy networks through two-stage procedure. The second FTCA scheme is based on the modified sensitivity factors. These factors are developed from the actual measurements of power flows in transmission lines and the power injections at different buses. The proposed schemes exhibit desirable apportioning properties and are easy to implement and understand. Case studies for different loading conditions are carried out to show the capability of the proposed schemes for solving the TCA problem.

10/00638 Trigeneration integrated with absorption enhanced reforming of lignite and biomass

Wang, Y. *et al. Fuel*, 2009, 88, (10), 2004–2010.

A technical investigation of an innovative trigeneration integrated with absorption enhanced reforming (AER) of lignite and biomass is carried out using the ECLIPSE process simulator. The system includes an internal combustion engine, an AER gasifier, a waste heat recovery and storage unit and an absorption refrigerator. The whole system is operated in the following sequence: The AER gasifier is used to generate hydrogen using lignite and biomass; the hydrogen generated is used to run the engine which drives a generator to produce electricity. Additionally, the heat recovery unit collects waste heat from the engine and is used to supply hot water and space heating. Furthermore, the waste heat is used to operate the absorption refrigerator. The electricity, heat and cooling can be used to meet the energy requirements for the households in a village, a resident building or a commercial building, or a supermarket. Within the study, the effects of lignite mixed with three different types of biomass (straw, willow and switch grass) on the system performance are investigated and the results are compared. The results show that it is feasible to use an AER system to reform the low quality fuels lignite and biomass to generate a cleaner fuel – hydrogen to replace fossil fuels (diesel or natural gas) and to fuel an engine based trigeneration system; the system works with high efficiencies and with a potential of carbon capture from the sorbent-regeneration process that would benefit the environment.

07 STEAM RAISING

Boiler operation/design

10/00639 Combining support vector regression and cellular genetic algorithm for multi-objective optimization of coal-fired utility boilers

Wu, F. *et al. Fuel*, 2009, 88, (10), 1864–1870.

Support vector regression (SVR) was employed to establish mathematical models for the NO_x emissions and carbon burnout of a 300 MW coal-fired utility boiler. Combined with the SVR models, the cellular genetic algorithm for multi-objective optimization (MOCell) was used for multi-objective optimization of the boiler combustion. Meanwhile, the comparison between MOCell and the improved non-dominated sorting genetic algorithm (NSGA-II) shows that MOCell has superior performance to NSGA-II regarding the problem. The field experiments were carried out to verify the accuracy of the results obtained by MOCell, the results were in good agreement with the measurement data. The proposed approach provides an effective tool for multi-objective optimization of coal combustion performance, whose feasibility and validity are experimental validated. A time period of less than 4 s was required for a run of optimization under a PC system, which is suitable for the online application.

10/00640 Development of new nickel based catalyst for biomass tar steam reforming producing H_2-rich syngas

Li, C. *et al. Fuel Processing Technology*, 2009, 90, (6), 790–796.

As documented in an earlier study, mayenite ($Ca_{12}Al_{14}O_{33}$ or $12CaO.7Al_2O_3$) was previously developed and applied as Ni support for biomass tar steam reforming in the absence and presence of H_2S because of its high oxygen restoring property in the structure. In this study, catalyst Ni/mayenite (mayenite as support) was prepared by impregnation method with nickel nitrate hexahydrate. Experiments were tested in a fixed-bed reactor, toluene as a tar model compound. The influence of the catalyst preparation and operating parameters (reaction temperature, steam to carbon ratio and space time) on catalyst activity and products selectivity were studied, and a long-time evaluation (more than 76 h) also exhibited excellent resistance to coking. These results were compared to these obtained by commercial-like catalysts: $Ni/CaO_x/MgO_{1-x}$ and the previous NiO/mayenite, showing that Ni/mayenite exhibited excellent property for biomass tar reforming, with higher H_2 yield than that of $Ni/CaO_x/MgO_{1-x}$, and higher CO selectivity than that of NiO/mayenite. For kinetic model, the first order reaction used for toluene with activation energy of 80.24 kJ mol^{-1} was coincident with literature data.

10/00641 Mathematical modeling and thermal-hydraulic analysis of vertical water wall in an ultra supercritical boiler

Pan, J. *et al. Applied Thermal Engineering*, 2009, 29, (11–12), 2500–2507.

Water wall design is a key issue for an ultra supercritical boiler. In order to increase the steam–water mixture turbulization and to prevent the burnout of tubes walls, vertical rifled tubes are applied in Yuhuan power plant boiler which is the first 1000 MW ultra supercritical boiler in China and began to operate in December 2006. Mathematical modelling and thermal-hydraulic analysis are key factors for the successful design and operation of water walls. The water wall system is treated in this paper as a network consisting of circuits, pressure grids and connecting tubes. The mathematical model for predicting the mass flux distribution and metal temperature in water wall is based on the mass, momentum and energy conservation equations. An experiment on the heat transfer characteristics of vertical rifled tube was conducted with the aim to obtain the heat transfer performance and corresponding empirical correlations. The fitting computational formulas are applied in the mathematical model. The presented modelling method is more accurate than the conventional graphic method and can be applied to complex circuit structures. The mass flux distribution and the metal temperature in the water wall are calculated at 35%, 50% and 100% of the boiler maximum continuous rating (BMCR). The results show a good agreement with the plant data. The maximum relative difference between the calculated mass flux and the plant data is 9.7% at 50% BMCR load. The metal temperature difference in the tip of fins in lower circuit 8 is about 3–7 °C at 35% BMCR load. The results show that the vertical water wall in the ultra supercritical boiler of Yuhuan power plant can operate safely.

10/00642 Regulation, pollution and heterogeneity in Japanese steam power generation companies

Barros, C. P. and Managi, S. *Energy Policy*, 2009, 37, (8), 3109–3129.

In this paper, the random stochastic frontier model is used to estimate the technical efficiency of Japanese steam power generation companies taking into regulation and pollution. The companies are ranked according to their productivity for the period 1976–2003 and homogenous and heterogeneous variables in the cost function are disentangled. Policy implication is derived.

08 COMBUSTION

Burners, combustion systems

10/00643 Cofiring coal and dairy biomass in a 29 kW$_t$ furnace

Lawrence, B. *et al. Applied Energy*, 2009, 86, (11), 2359–2372.

Cofiring biomass with fossil fuels is emerging as a viable option for promoting the use of low-quality renewable biomass fuels including energy crops. In the current work, dairy biomass (DB) is evaluated as a cofiring fuel with coal in a small scale 29 kW$_t$ boiler burner facility. Two types of coal (Texas lignite, TXL and Wyoming Powder River Basin coal, WYO) and two forms of partially composted DB fuels were investigated (low ash separated solids LA-PC-SepSol-DB and high ash soil surface HA-PC-SoilSurf-DB). Proximate and ultimate analyses performed on both coals and both DBs reveal the following: higher heating value (HHV) of 28,460–29,590 kJ/kg for dry ash free (DAF) coals and 21,450 kJ/kg for DB; nitrogen loading of 0.36 and 0.48 kg/GJ for WYO and TXL, respectively and 1.50 and 2.67 kg/GJ for the LA-PC-SepSol-DB and the HA-PC-SoilSurf-DB respectively; sulfur loading of 0.15 and 0.42 kg/GJ WYO and TXL, respectively and 0.33 and 0.43 kg/GJ for the LA-PC-SepSol-DB and the HA-PC-SoilSurf-DB respectively; ash loading from 3.10 to 8.02 kg/GJ for the coals and from 11.57 to 139 kg/GJ for the DB fuels. The cofiring experiments were performed with 90:10 and 80:20 and 100:00 (mass%) coal:DB blend (96:4, 92:8, 100:00 – per cent on heat basis). The results revealed that the blend burns more completely in the boiler, due to the earlier release of biomass volatiles and higher amount of volatile matter. Results were obtained for burnt fraction, NO$_x$ and CO emission. Pure TXL produced 1505 ppm of CO at an equivalence ratio of 1.1. An 80:20 blend of TXL:LA-PC-SepSol-DB produced 4084 ppm of CO at the same equivalence ratio. The NO$_x$ emissions for equivalence ratio varying from 0.9 to 1.2 ranged from 0.4 to 0.13 kg/GJ for pure TXL coal. The corresponding NO$_x$ emissions are 0.8–0.10 kg/GJ for pure WYO coal. For 80:20 TXL:LA-SepS-DB blend they ranged from 0.375 to 0.05 kg/GJ over the same range. In general, the blends produced less NO$_x$ than pure coal under rich conditions even though the DB contained more nitrogen. This result is probably due to the fuel bound nitrogen in dairy biomass is mostly in the form of urea which reduces NO$_x$ to N$_2$.

10/00644 Combustion characteristics of lignite-fired oxy-fuel flames

Hjärtstam, S. *et al. Fuel*, 2009, 88, (11), 2216–2224.

This experimental work describes the combustion characteristics of lignite-fired oxy-fuel flames, in terms of temperature distribution, gas composition (O$_2$, CO$_2$, CO, total hydrocarbon concentration and NO) and ignition behaviour. The aim is to evaluate the flame structure of three oxy-fuel cases (obtained by changing the flue gas recycle rate) including a comparison with an air-fired reference case. Measurements were performed in Chalmers 100 kW test unit, which facilitates oxy-fuel combustion under flue gas recycling conditions. Temperature, O$_2$ and CO concentration profiles and images of the flames indicate that earlier ignition and more intense combustion with higher peak temperatures follow from reduction of the recycle rate during oxy-fuel operation. This is mostly due to higher O$_2$ concentration in the feed gas, reduced cooling from the recycled flue gas, and change in flow patterns between the cases. The air case and the oxy-fuel case with the highest recycle rate were most sensitive to changes in overall stoichiometry. Despite significant differences in local CO concentration between the cases, the stack concentrations of CO are comparable. Hence, limiting CO emissions from oxy-fuel combustion is not more challenging than during air-firing. The NO emission, as shown previously, was significantly reduced by flue gas recycling.

10/00645 Dynamics and stability of lean-premixed swirl-stabilized combustion

Huang, Y. and Yang, V. *Progress in Energy and Combustion Science*, 2009, 35, (4), 293–364.

Combustion instability remains a critical issue limiting the development of low-emission, lean-premixed (LPM) gas turbine combustion systems. The present work provides a comprehensive review of the advances made over the past two decades in this area. Recent developments in industrial dry-low-emission (DLE) swirl-stabilized combustors are first summarized. Various swirl injector configurations and related flow characteristics, including vortex breakdown, precessing vortex core, large-scale coherent structures, and liquid fuel atomization and spray formation, are discussed. Non-linear behaviours of combustion processes observed in combustors are described. The influence of fuel preparation, combustor geometry, and operating conditions on combustion characteristics in swirl-stabilized combustors is examined. The mechanisms driving combustion instabilities, including hydrodynamic instabilities, equivalence ratio fluctuations, flame surface variations, and oscillatory liquid fuel atomization and evaporation are investigated. Instability stabilization methods, including both passive and active control techniques, are also reviewed. Finally, recent progress in both analytical modelling and numerical simulation of swirl-stabilized combustion are surveyed.

10/00646 Effect of the radiation surface on temperature and NO$_x$ emission in a gas fired furnace

Boke, Y. E. and Aydin, O. *Fuel*, 2009, 88, (10), 1878–1884.

A significant increase in the efficiency of furnaces burning natural gas is achieved by increasing the radiation heat transfer from the flame. In this study, the effect of cylindrically shaped additional radiation surface called, filling material (FM), on emissions and temperature distribution in the combustion chamber (CC) was investigated experimentally. Experiments were carried out on a fire tube water heater described in the standard EN 676 for the firing rates of 58, 87 and 116 kW. Two diameters of the filling materials, 25 and 30 cm, and two lengths of 20 and 40 cm were considered. The flame temperature and nitrogen oxide (NO) emission were measured for different positions and geometries of the filling material in the combustion chamber. The flame temperature and the temperature drop of the flame in the back flow increased with the increasing diameter and length of the filling materials compared to the case without filling material. It was observed that the filling material with the larger diameter increased the heat transfer rate in the back flow compared to the case without filling material. The in-furnace measured NO concentration was in good agreement with NO concentration in the well-mixed flue gas. The 20 cm long filling materials decreased the NO emission. Increased length of the filling material resulted in increased the NO emission.

10/00647 Examination of the combustion conditions of herbaceous biomass

Szemmelveisz, K. *et al. Fuel Processing Technology*, 2009, 90, (6), 839–847.

Power generation from biomass is a fairly new area, and boilers that utilize various types of biomass have in many cases experienced serious problems with slagging, fouling and corrosion of boiler tubes. Mineral matter in these fuels can deposit on the heat-exchanger surfaces in the boiler and generate an insulating layer, which will significantly reduce the degree of heat-transfer from flue gas to water and steam. The investigations were focused on the slag characteristics of different kinds of herbaceous biomass fuels. Since there is usually a reducing atmosphere present in the direct combustion zone of modern low-NO$_x$ firing systems, it is important to study mineral matter transformation of burned fuel residues in a reducing atmosphere. An excellent device for this type of study is the electric-resistance heated Bunte–Baum softening temperature testing instrument, which was used in this work. Ash chemical composition was analysed via flame atomic absorption spectrometry and the microstructure of ash was determined using a scanning electron microscope. Crystalline compounds of the ashes were identified by using X-ray powder diffraction. This paper provides an overview of results on the combustion and slag characteristics of herbaceous biomass fuels. The results include chemical compositions, morphology and softening properties of these fuels, with special attention to switch grass and sunflower seed shell.

10/00648 Experimental study on the laminar flame speed of hydrogen/carbon monoxide/air mixtures

Dong, C. *et al. Fuel*, 2009, 88, (10), 1858–1863.

Carbon monoxide and hydrogen are two important components in syngas. In this study, the laminar flame speed of hydrogen/carbon monoxide fuel mixtures is measured over a large range of fuel compositions (0–100% volume fraction for hydrogen in the mixture) by using a Bunsen burner. The reaction zone area is used to calculate the laminar flame speed. The equivalence ratio covers from lean conditions to rich conditions. The experimental results show that by using the Bunsen flame, the laminar flame speed calculated with the reaction zone area is reliable. Based on the experimental results, empirical equations are derived which can be readily employed to calculate the laminar flame speeds of hydrogen, carbon monoxide, and hydrogen/carbon monoxide mixtures.

10/00649 Fast pyrolysis comparison of coal–water slurry with its parent coal in Curie-point pyrolyser

Wang, H. *et al. Energy Conversion and Management*, 2009, 50, (8), 1976–1980.

Curie-point pyrolyser is an instrument that can be used to analyse powder or slurry samples at medium heating rates. It can keep a constant heating rate to heat up the samples until the wire temperature reaches Curie-point temperature and remains the same temperature. In this paper, coal–water slurry (CWS) and its parent coal were studied by using a Curie-point pyrolyser. Kinetic parameters of pyrolysis were calculated and apparent activation energy of CWS obtained is 16.362 kJ/mol, which is a little higher than that of its parent coal, 12.691 kJ/mol. The experimental curves show lean S shape and the heating rate are obtained, which are 617 K/s and 834 K/s, respectively.

10/00650 Flame spread over thin fuels in actual and simulated microgravity conditions

Olson, S. L. *et al. Combustion and Flame*, 2009, 156, (6), 1214–1226.

Most previous research on flame spread over solid surfaces has involved flames in open areas. In this study, the flame spreads in a narrow gap, as occurs in fires behind walls or inside electronic equipment. This geometry leads to interesting flame behaviours not typically seen in open flame spread, and also reproduces some of the conditions experienced by microgravity flames. Two sets of experiments are described, one involving flame spread in a narrow channel apparatus (NCA) in normal gravity, and the others taking place in actual microgravity. Three primary variables are considered: flow velocity, oxygen concentration, and gap size (or effect of heat loss). When the oxidizer flow is reduced at either gravity level, the initially uniform flame front becomes corrugated and breaks into separate flamelets. This breakup behaviour allows the flame to keep propagating below standard extinction limits by increasing the oxidizer transport to the flame, but has not been observed in other microgravity experiments due to the narrow samples employed. Breakup cannot be studied in typical (i.e. 'open') normal gravity test facilities due to buoyancy-induced opposed flow velocities that are larger than the forced velocities in the flamelet regime. Flammability maps are constructed that delineate the uniform regime, the flamelet regime, and extinction limits for thin cellulose samples. Good agreement is found between flame and flamelet spread rate and flamelet size between the two facilities. Supporting calculations using FLUENT suggest that for small gaps buoyancy is suppressed and exerts a negligible influence on the flow pattern for inlet velocities ≥ 5 cm/s. The experiments show that in normal gravity the flamelets are a fire hazard since they can persist in small gaps where they are hard to detect. The results also indicate that the NCA quantitatively captures the essential features of the microgravity tests for thin fuels in opposed flow.

10/00651 Flame–vortex interaction driven combustion dynamics in a backward-facing step combustor

Altay, H. M. *et al. Combustion and Flame*, 2009, 156, (5), 1111–1125.

The combustion dynamics of propane–hydrogen mixtures are investigated in an atmospheric pressure, lean, premixed backward-facing step combustor. The authors systematically vary the equivalence ratio, inlet temperature and fuel composition to determine the stability map of the combustor. Simultaneous pressure, velocity, heat release rate and equivalence ratio measurements and high-speed video from the experiments are used to identify and characterize several distinct operating modes. When fuel is injected far upstream from the step, the equivalence ratio entering the flame is temporally and spatially uniform, and the combustion dynamics are governed only by flame–vortex interactions. Four distinct dynamic regimes are observed depending on the operating parameters. At high but lean equivalence ratios, the flame is unstable and oscillates strongly as it is wrapped around the large unsteady wake vortex. At intermediate equivalence ratios, weakly oscillating quasi-stable flames are observed. Near the lean blowout limit, long stable flames extending from the corner of the step are formed. At atmospheric inlet temperature, the unstable mode resonates at the 1/4 wavemode of the combustor. As the inlet temperature is increased, the 5/4 wavemode of the combustor is excited at high but lean equivalence ratios, forming the high-frequency unstable flames. Higher hydrogen concentration in the fuel and higher inlet temperatures reduce the equivalence ratios at which the transitions between regimes are observed. The authors plot combustion dynamics maps or the response curves, that is the overall sound pressure level as a function of the equivalence ratio, for different operating conditions. The study demonstrates that numerical results of strained premixed flames can be used to collapse the response curves describing the transitions among the dynamic modes onto a function of the heat release rate parameter alone, rather than a function dependent on the equivalence ratio, inlet temperature and fuel composition separately. The authors then formulate a theory for predicting the critical values of the heat release parameter at which quasi-stable to unstable and unstable to high-frequency unstable modes take place.

10/00652 Flux distribution of solar furnace using non-imaging focusing heliostat

Lim, C. S. and Li, L. *Solar Energy*, 2009, 83, (8), 1200–1210.

This paper discusses on the flux distribution of a quasi-single stage solar furnace, which consists of a non-imaging focusing heliostat as the primary stage and a much smaller spherical concentrator as a secondary. As the optics of the primary stage heliostat is of non-imaging nature, the analytical method for studying the flux distribution of the hot spot of this type of solar furnace would be complicated. Therefore, a digital simulation approach has been employed. Flux distributions of the hot spot for several different incident angles, which have covered all the extreme cases of operating conditions have been simulated. Simulation result shows that a solar furnace using an 8 × 8 m non-imaging focusing heliostat with 289 mirrors coupled with a spherical concentrator with 0.7 m aperture and 27 cm focal length is theoretically capable of achieving flux concentration of 25,000 suns. Concentration contours of flux distribution for several interesting cases are presented, the different working areas of high flux footage from 5000 to 15,000 suns have been compiled.

10/00653 Improvement of micro-combustion stability through electrical heating

Zhou, J. *et al. Applied Thermal Engineering*, 2009, 29, (11–12), 2373–2378.

This experiment investigates the performance of a micro combustor under different operation conditions, and its improvement with electrical heating inside. According to the results, extinction and blow out occurred at 0.08 and 0.4 L/min, respectively. Electrical heating enhanced the stability effectively. With electrical heating power of 1.05 and 4.70 W, the equivalence ratio ranges of stable combustion are extended from 0.362 – 6.52 to 0.178 – 7.66 and 0.126 – 9.43 on average, respectively, and it is more effective in the lean and low-flow-rate cases. The micro flame shows obvious shift downstream at high flow rates. The flames in the lean cases have higher robustness, their reaction region are closer to the nozzle outlet around 1.17 mm on average than in the rich cases. The heat loss and heat conduction of the micro combustor surface are found to be related to its performance. The rich cases at moderate flow rates have 0.086 W lower heat loss on average than the lean cases, which enhances the stability effectively. However, the rich cases have 0.013 W lower heat conduction on average at moderate flow rates, thus more severe shift downstream occurs.

10/00654 Influence of HCl on CO and NO emissions in combustion

Wei, X. *et al. Fuel*, 2009, 88, (10), 1998–2003.

The influence of HCl on CO and NO emissions was experimentally investigated in an entrained flow reactor (EFR) and an internally circulating fluidized bed (ICFB). The results in EFR show the addition of HCl inhibits CO oxidation and NO formation at 1073 K and 1123 K. At the lower temperature (1073 K) the inhibition of HCl becomes more obvious. In ICFB, chlorine-containing plastic (PVC) was added to increase the concentration of HCl during the combustion of coal or coke. Results show that HCl is likely to enhance the reduction of NO and N_2O. HCl greatly increases CO and CH_4 emission in the flue gas. A detailed mechanism of CO/NO/HCl/SO_2 system was used to model the effect of HCl in combustion. The results indicate that HCl not only promotes the recombination of radicals O, H, and OH, but also accelerates the chemical equilibration of radicals. The influence of HCl on the radicals mainly occurs at 800–1200 K.

10/00655 Investigation of combustion kinetics of treated and untreated waste wood samples with thermogravimetric analysis

Yorulmaz, S. Y. and Yorulmaz, A. T. *Fuel Processing Technology*, 2009, 90, (7–8), 939–946.

In the present study, combustion mechanisms, thermal kinetics, and phases of combustion were investigated for waste wood samples (untreated pine and treated MDF, plywood and particleboard). Waste wood samples were combusted in air at 10, 20 and 30 °C/min heating rates in TGA. The results of TG analysis have shown that thermal decomposition of treated samples takes place at lower temperatures as compared to the untreated pine sample because of the catalysing effects of the chemicals in the samples. Therefore, there were less flammable products, lower weight losses in the main oxidation region, and decrease in the maximum weight loss temperatures and formation of more char for treated samples as compared to untreated pine sample. Thermal kinetic constants for the samples were calculated by using Coats Redfern Method. In order to find out the mechanisms responsible for the oxidation of the waste wood samples, six solid-state mechanisms of Coats Redfern Method were tested. The results of the Coats Redfern Method have shown that diffusion mechanism is the effective mechanism for all regions of the pine samples. For the main oxidation region, D4 mechanism (Ginstling–Brounshtein equation) was found to be the main diffusion mechanism for pine samples. For the treated samples such as MDF, plywood and particleboard, first-order reaction (F1) was found as an effective mechanism. Treatment of wood with different additives and glues seemed to alter the thermal oxidation process and change the effective oxidation mechanisms.

10/00656 Laser diagnostics of trace species in low-pressure flat flame

Cheskis, S. and Goldman, A. *Progress in Energy and Combustion Science*, 2009, 35, (4), 365–382.

Laser-based diagnostic methods can measure the absolute concentrations of various atoms and molecules, even at low concentrations. They can also measure temperature with high accuracy. One very important advantage of these methods is the ability to make measurements without affecting the studied process, for example flame. Laser-based spectroscopy can thus provide important information for the validation of chemical mechanisms in well-defined, low-pressure flat flames. This paper reviews several methods: laser-induced fluorescence, cavity ring-down spectroscopy, intracavity laser absorption spectroscopy, and polarization spectroscopy. All four are sufficiently sensitive to measure the concentrations of trace species in low-pressure flat flames. The complementarity of the methods for combustion diagnostics is also discussed.

10/00657 Long-term integrity testing of spray-dried particles in a 10-kW chemical-looping combustor using natural gas as fuel

Linderholm, C. *et al. Fuel*, 2009, 88, (11), 2083–2096.

Chemical-looping combustion, CLC, is a combustion concept with inherent separation of CO_2. The fuel and combustion air are kept apart by using an oxygen carrier consisting of metal oxide. The oxygen carriers used in this study were prepared from commercially available raw materials by spray-drying. The aim of the study was to subject the particles to long-term operation (>1000 h) with fuel and study changes in particles, with respect to reactivity and physical characteristics. The experiments were carried out in a 10-kW chemical-looping combustor operating with natural gas as fuel. 1016 h of fuel operation were achieved. The first 405 h were accomplished using a single batch of $NiO/NiAl_2O_4$-particles. The last 611 h were achieved using a $50/50_{mass}$-mixture of (i) particles used for 405 h, and (ii) a second batch of particles similar in composition to the first batch, but with an MgO additive. Thus, at the conclusion of the test series, approximately half of the particles in the reactor system had been subjected to >1000 h of chemical-looping combustion. The reason for mixing the two batches was to improve the fuel conversion. Fuel conversion was better with the mixture of the two oxygen carriers than it was using only the batch of $NiO/NiAl_2O_4$-particles. The CO fraction was slightly above the equilibrium fraction at all temperatures. Using the oxygen carrier mixture, the methane fraction was typically 0.4–1% and the combustion efficiency was around 98%. The loss of fines decreased slowly throughout the test period, although the largest decrease was seen during the first 100 h. An estimated particle lifetime of 33,000 h was calculated from the loss of fines. No decrease in reactivity was seen during the test period.

10/00658 Simulation of turbulent combustion and NO formation in a swirl combustor

Peng, L. and Zhang, J. *Chemical Engineering Science*, 2009, 64, (12), 2903–2914.

A presumed probability density function (PDF) model for temperature fluctuation is proposed and formulated in this paper. It incorporates a two-step reaction mechanism for propane combustion and the thermal and prompt NO formation mechanisms. The present model, together with a new algebraic Reynolds stress model (ASM), is employed to simulate the turbulent combustion and NO formation in a swirl combustor. The calculated propane, carbon monoxide, and carbon dioxide concentrations agree with the measurement. The calculated gas temperature and oxygen and NO concentrations are in general agreement with the measured data. The simulated results show that NO forms mainly in the upstream region of the combustor. The flue gas recirculation effectively abates the nitrogen oxides (NO_x) emission in the combustor.

10/00659 Single and two-stage electrostatic demisters for biomass pyrolysis application

Bedmutha, R. J. *et al. Chemical Engineering and Processing: Process Intensification*, 2009, 48, (6), 1112–1120.

Single-stage and two-stage tubular electrostatic precipitators were designed. A nitrogen stream containing very fine droplets of fogging oil was forced through the electrostatic precipitator chamber. It was found that 98.6 wt% of the oil droplets present in the turbulent jet were mechanically collected on the inner walls of the test chamber. When the electrode was energized at 13 kV, 92.37 wt% of the droplets that had not been mechanically separated were collected in single-stage mode. The collection efficiency was increased to 93.18 wt%, when the electrostatic precipitator was operated in two-stage mode. Voltage–current (V–I) characteristics of the single-stage and two-stage electrostatic precipitators were studied in detail for different test conditions. Nitrogen impurities played a major role in determining the V–I characteristics. They became less relevant with the introduction of mist in the nitrogen stream, presumably due to the presence of water vapour in the gas. The two-stage tubular electrostatic precipitator was scaled up and tested on a fluidized bed pilot plant used for the pyrolysis of biomass. A droplet collection efficiency of 95 wt% was observed. Such demisters will extend, to the product recovery train, the process intensification gains of short residence time processes such as fast pyrolysis.

10/00660 The effect of air preheating in a biomass CFB gasifier using ASPEN Plus simulation

Doherty, W. *et al. Biomass and Bioenergy*, 2009, 33, (9), 1158–1167.

In the context of climate change, efficiency and energy security, biomass gasification is likely to play an important role. Circulating fluidized bed (CFB) technology was selected for the current study. The objective of this research is to develop a computer model of a CFB biomass gasifier that can predict gasifier performance under various operating conditions. An original model was developed using ASPEN Plus. The model is based on Gibbs free energy minimization. The restricted equilibrium method was used to calibrate it against experimental data. This was achieved by specifying the temperature approach for the gasification reactions. The model predicts syn-gas composition, conversion efficiency and heating values in good agreement with experimental data. Operating parameters were varied over a wide range. Parameters such as equivalence ratio (ER), temperature, air preheating, biomass moisture and steam injection were found to influence syn-gas composition, heating value, and conversion efficiency. The results indicate an ER and temperature range over which hydrogen (H_2) and carbon monoxide (CO) are maximized, which in turn ensures a high heating value and cold gas efficiency (CGE). Gas heating value was found to decrease with ER. Air preheating increases H_2 and CO production, which increases gas heating value and CGE. Air preheating is more effective at low ERs. A critical air temperature exists after which additional preheating has little influence. Steam has better reactivity than fuel bound moisture. Increasing moisture degrades performance therefore the input fuel should be pre-dried. Steam injection should be employed if a H_2 rich syngas is desired.

10/00661 The effects of turbulence-induced time-periodic shear on a flame anchored to a propellant

Isfahani, A. H. G. *et al. Combustion and Flame*, 2009, 156, (5), 1048–1098.

This study examines the combustion response of a flame anchored to two 1/4-spaces of solid fuel and oxidizer, a configuration relevant to the combustion of heterogeneous solid propellants. A time-periodic shear flow is applied to model the shear that can be generated by the presence of acoustics or turbulence in a rocket chamber. To estimate the magnitude and frequency of the shear for the case of a turbulent flow, the authors present DNS results of a planar periodic rocket, a configuration that has its roots in a multiscale analysis. Such a configuration allows for the determination of the shear parameters as a function of motor geometry and downstream location. The response of the flame to this shear, the heat flux to the surface, and the burning rate are calculated numerically. Significant enhancement to the burn rate, commonly known as erosive burning, is found.

10/00662 The influence of included minerals on the intrinsic reactivity of chars prepared at 900 °C in a drop tube furnace and a muffle furnace

Zhang, H. *et al. Fuel*, 2009, 88, (11), 2303–2310.

Two fractions, representing organic-rich particles and organic particles with included minerals, were separated from each of four Chinese coals of different rank. They were then devolatilized at 900 °C in a drop tube furnace (DTF) and a muffle furnace, respectively. The chars were subjected to thermogravimetric analysis, SEM observation and a nitrogen adsorption study. It was found that when three conditions were all met, high mineral content, high volatile content and high heating rate, the included minerals show inhibition on combustion. Otherwise, the included minerals show promotion. Mechanism analysis shows that this is the result of an interaction between the liquid phase and mineral matter during devolatilization. In cases when there is no, or little, liquid phase the included minerals act as pore producer in the coal matrix. Otherwise, the included minerals dilute and absorb the liquid phase, leading to the formation of a char structure with fewer voids and more ordered structure, thus, lower reactivity.

10/00663 The negative effects of alcohols on carbon nanotube synthesis in a nebulised spray pyrolysis process

Cele, L. M. and Coville, N. J. *Carbon*, 2009, 47, (7), 1824–1832.

Multi-walled carbon nanotubes were synthesized by the nebulized spray pyrolysis (frequency 1.6 MHz) of toluene and toluene–alcohol mixtures with ferrocene as the catalyst precursor. The CNTs produced were characterized by TEM, SEM, laser-Raman spectroscopy and TGA. The results show that the presence of ethanol, 2-propanol and octanol in the reaction mixture reduces the CNT yield, growth rate and produces CNTs that are less well graphitized and less resistant to oxidation. The data suggests that the exposure of the alcohol-containing mixture to ultrasound irradiation results in the production of radicals that inhibit CNT formation.

10/00664 Wood ash dilemma-reduced quality due to poor combustion performance

Sarenbo, S. *Biomass and Bioenergy*, 2009, 33, (9), 1212–1220.

Recycling of wood ash is based on the presumption that moderate concentrations of environmentally harmful elements are a part of the nutrient cycle and do not increase in net concentrations in the forest soil. It is assumed that the same quantities of harmful elements are harvested from the forest and recycled back. This principle does not apply to polycyclic aromatic hydrocarbons (PAHs) since these pollutants are formed during the combustion process, especially when the combustion performance is poor. Additionally, industrial combustors are adjusted in order to reduce NO_x-emissions, indirectly causing formation of PAHs. This study examined fly ash from combustion of pulverized wood for its elemental and PAH concentrations during a period of 9 weeks. The 16 EPA-PAH concentrations range between 40 and 300 mg kg^{-1}. Re-burning of the ash reduces the PAH concentrations to 0.24 mg kg^{-1} and organic carbon concentration from 40% to 5%, enhancing its composition significantly. It is important to determine the amount and fate of PAHs spread on forest soils with wood ash to ensure the improvement of the health of the forest ecosystem. Maximized energy efficiency of industrial boilers is the key to reducing anthropogenic emissions of greenhouse gases and enabling a sustainable nutrient recycling system.

Fire safety

10/00665 Investigating the effect of computational grid sizes on the predicted characteristics of thermal radiation for a fire

Lin, C. H. *et al. Applied Thermal Engineering*, 2009, 29, (11–12), 2243–2250.

Recently, the phenomenological modelling of fires has been shifted from the engineering application of correlation-based methods to the computational fluid dynamics (CFD) techniques. Therefore, the majority of this paper is to investigate the effects of grid sizes on the predicted radiative characteristics involved in a fire using CFD simulations, with the aim of selecting the appropriate grid size under the consideration of prediction accuracy and computing cost. Based on the present simulations, the predicted flame height increases as the decreasing grid size and would approach to a quasi-steady value if the simulation grids are adopted to be small enough. Similar results are also revealed in the radiative heat flux behaviours. The predicted distributions of radiative heat fluxes have no significant variations as the grid size is reduced to some small value. Several experiments of small pool fires with various diameters (20–38 cm) are conducted to assess the present CFD predictions. Using the appropriate grid size, the predicted results for radiative heat fluxes and flame heights show good agreement with the experimental data for different-size pool fires. This grid size suggested in this paper could assist the CFD simulations of pool fires in obtaining the accurate enough predictions with reasonable computing time.

10/00666 Prediction of the extent of diluents concentrations in flammability limited gaseous fuel–diluent mixtures in air

Bade Shrestha, S. O. *et al. Applied Thermal Engineering*, 2009, 29, (11–12), 2574–2578.

A method is described for estimating the maximum diluent concentration in a gaseous fuel–diluent mixture in air that would just render flame propagation from an ignition source possible at different initial temperature conditions. This would also correspond to the threshold of diluent concentration needed to prevent fire spread within the mixture. Only knowledge of the flammability limit values of the pure fuel on its own in air at atmospheric pressure and temperature conditions are needed. The common gaseous fuel–diluent mixtures considered included methane, ethylene, propane, butane, carbon monoxide and hydrogen with the diluents nitrogen, carbon dioxide, helium and argon. It is shown that there is a satisfactory agreement between predicted and corresponding experimental values.

10/00667 Utility theoretic semi-logarithmic incomplete demand systems in a natural experiment: forest fire impacts on recreational values and use

Hilger, J. and Englin, E. *Resource and Energy Economics*, 2009, 31, (4), 287–298.

This study develops a utility theoretic demand model for an arbitrary number of goods that handles correlation between goods and over time. The bivariate compound Poisson estimator is applied to a semi-logarithmic incomplete demand system to estimate the demand for wilderness recreation and the associated welfare measures both prior to and post a 40,000-acre wilderness fire in Washington. Forest fires can simultaneously affect the environmental qualities of many recreational sites; this highlights the need for a utility theoretic demand system approach for modelling consumer behaviour that handles the dynamic behavioural and statistical interdependencies over goods and time. Results suggest an increase in consumer welfare per trip post fire, after an initial period of low values, relative to before the fire.

09 PROCESS HEATING, POWER AND INCINERATION

Energy applications in industry

10/00668 A critical comparison of frictional stress models applied to the simulation of bubbling fluidized beds

Passalacqua, A. and Marmo, L. *Chemical Engineering Science*, 2009, 64, (12), 2795–2806.

The behaviour of a gas–solid flow in a bubbling fluidized bed operated near the minimum fluidization condition is strongly influenced by the frictional stresses between the particles, these being highly concentrated and their motion dominated by enduring contact among them and with the walls. The effect of the introduction of frictional stresses in a Eulerian–Eulerian two fluid model based on the kinetic theory of the granular flow is evaluated. Earlier models are compared with the kinetic theory of the granular flow and with experimental data both in a bubbling fluidized bed with a central jet and in a bubbling fluidized bed with a porous distributor. The predicted evolution of the bubble diameter along the height of the fluidized beds is examined, the shapes of the bubbles predicted by the models are compared and the evolution in time of the bubbles is shown. In the case of the bed with a central jet, the bubble detachment time is also calculated. The results show that the introduction of a frictional stress model improves the prediction of the bubbles diameter in a bubbling fluidized bed with a central jet and positively affects the bubbles diameter distribution in a uniformly fed bubbling fluidized bed. The high sensitivity of the model to the value of the particulate phase fraction at which frictional stresses start to be accounted for is pointed out through a sensitivity analysis performed on the Srivastava and Sundaresan model.

10/00669 A novel method for estimating the initial rotor position of PM motors without the position sensor

Rostami, A. and Asaei, B. *Energy Conversion and Management*, 2009, 50, (8), 1879–1883.

Permanent magnet (PM) motors have been used widely in the industrial applications. However, a need of the position sensor is a drawback of their control system. The sensorless methods using the back-EMF (electromotive force) cannot detect the rotor position at a standstill; recently, a few methods proposed to detect the initial rotor position, but they have high estimation error which reduces starting torque of the motor. Therefore, in this paper, a novel method to detect the initial rotor position of the PM motors is proposed, first, by using a space vector model, response of the stator current space vector to the saturation of the stator core is analysed; then a novel method based on the saturation effect is presented that estimates the initial rotor position and the maximum estimation error is less than 3.8°. Simulation results confirm this method is effective and precise, and variation of the motor parameters does not affect its precision.

10/00670 A Swedish integrated pulp and paper mill – energy optimisation and local heat cooperation

Klugman, S. *et al. Energy Policy*, 2009, 37, (7), 2514–2524.

Heat cooperation between industries and district heating companies is often economically and environmentally beneficial. In this paper, energy cooperation between an integrated Swedish pulp and paper mill and two nearby energy companies was analysed through economic optimizations. The synergies of cooperation were evaluated through optimizations with different system perspectives. Three changes of the energy system and combinations of them were analysed. The changes were process integration, extending biofuel boiler and turbine capacity and connection to a local heat market. The results show that the single most promising system change is extending biofuel and turbine capacity. Process integration within the pulp and paper mill would take place through installing evaporation units that yield less excess heat but must in this particular case be combined with extended biofuel combustion capacity in order to be beneficial. Connecting to the local heat market would be beneficial for the pulp and paper mill, while the studied energy company needs to extend its biofuel capacity in order to benefit from the local heat market. Furthermore, the potential of reducing CO_2 emissions through the energy cooperation is shown to be extensive; particularly if biofuel and turbine capacity is increased.

10/00671 Climate policy impacts on the competitiveness of energy-intensive manufacturing sectors

Bassi, A. M. *et al. Energy Policy*, 2009, 37, (8), 3052–3060.

This study examines the impacts of energy price changes resulting from different carbon-pricing policies on the competitiveness of selected US energy-intensive industries. It further examines possible industry responses, and identifies and provides a preliminary evaluation of potential opportunities to mitigate these impacts. The industry sectors investigated – steel, aluminium, chemicals and paper – are among the largest industrial users of fossil fuels in the US economy. The results of this examination show that climate policies that put a price on carbon could have substantial impacts on the competitiveness of US energy-intensive manufacturing sectors over the next two decades, if climate regulations are applied only in the United States, and no action is taken to invest in advanced low- and no-carbon technologies. The extent of these impacts will vary across industries, depending on their energy intensities, the mix of energy sources they rely on and how energy is used in production activities (heat and power, feedstock). Of relevance is also the speed and rigor with which industries adopt new technologies and retire (or replace) old ones. Other factors affecting these impacts include an industry's vulnerability to foreign imports and its ability to pass through cost increases to its customers in the face of international market competition.

10/00672 Combustion of hydrogen in a bubbling fluidized bed

Baron, J. *et al. Combustion and Flame*, 2009, 156, (5), 975–984.

The combustion of hydrogen in a hot, bubbling bed of quartz sand fluidized by air has been studied for the first time, by injecting hydrogen just above the distributor, via six horizontal fine tubes of Cr/Ni. Overall the fluidizing gas was oxygen-rich, with the composition varying from nearly stoichiometric to very lean mixtures. With the bed initially fluidized at room temperature, combustion (after ignition by a pilot flame) occurs in a premixed flame sitting on top of the bed. When the sand warms up, combustion becomes explosive in bubbles leaving the bed, exactly as with a hydrocarbon as fuel. However, in contrast to hydrocarbons, it is clear that when the bed reaches 500–600 °C, heat is produced both above the top of the bed (because of H_2 bypassing the bed) and very low down in the bed. In fact, with hydrogen as fuel, the location of where bubbles ignite descends abruptly to low in the sand; furthermore, the descent occurs at ~500 °C, which is ~100 K below the ignition temperature predicted by well-established kinetic models. However, the kinetic models do reproduce the observations, if it is assumed that the Cr/Ni hypodermic tubes, through which the fuel was injected, exert a catalytic effect, producing free H atoms, which then give rise to HO_2 radicals. In this situation, kinetic modelling indicates that bubbles ignite when they become sufficiently large and few enough to have a lifetime (*i.e.* the interval between their collisions) longer than the ignition delay for the temperature of the sand. The amounts of NO found in the off-gases were at a maximum (24 ppm), when the bed was at ~500 °C for $\lambda = [O_2]/[O_2]_{\mathrm{stoich}} = 1.05$. The variations of [NO] with $[\mathrm{air}]/[H_2]$ and also temperature indicate that NO is produced, at least partly, via the intermediate N_2H. In addition, the air-afterglow emission of green light (from $NO + O \rightarrow NO_2 + h\nu$) was observed in the freeboard, indicating the presence there of both NO and free atoms of oxygen for $1.05 < \lambda < 1.1$.

10/00673 Computation of stabilizing PI and PID controllers by using Kronecker summation method

Fang, J. *et al. Energy Conversion and Management*, 2009, 50, (7), 1821–1827.

In this paper, a new method for computation of all stabilizing PI controllers is given. The method is based on the plant model in time domain, and by using the extraordinary feature results from Kronecker sum operation, an explicit equation of control parameters defining the stability boundary in parametric space is obtained. Beyond stabilization, the method is used to shift all poles to a shifted half plane that guarantees a specified settling time of response. The stability regions of PID controllers are given in (k_p, k_i), (k_p, k_d) and (k_i, k_d) plane, respectively. The proposed method is also used to compute all the values of a PI controller stabilizing a control system with uncertain parameters. The proposed method is further extended to determine stability regions of uncertain coefficients of the system. Examples are given to show the benefits of the proposed method.

10/00674 Conventional and modified fluidized bed: comparison of the fluid dynamics and application in particle granulation

da Cunha, R. L. G. *et al. Chemical Engineering and Processing: Process Intensification*, 2009, 48, (5), 1004–1011.

The goal of this study was to evaluate the fluid dynamic behaviour of both conventional and draft tube fluidized beds, with and without injection of compressed air (at 68.95, 103.42 and 137.89 kPa) to assess their suitability for granulation. A 35% maltodextrin solution was sprayed on microcrystalline cellulose particles by a double-fluid nozzle. The tube heights tested indicate an 8 cm maximum height from the distribution plate. Beyond this value, fluidization is similar to that of a conventional bed. The growth occurred by nucleation and consolidation of particles and the post-granulation parameters analysed were growth, angle of repose and granule circularity.

10/00675 Economical assessment of competitive enhanced limestones for CO_2 capture cycles in power plants

Romeo, L. M. *et al. Fuel Processing Technology*, 2009, 90, (6), 803–811.

CO_2 capture systems based on the carbonation/calcination loop have gained rapid interest due to promising carbonator CO_2 capture efficiency, low sorbent cost and no flue gases treatment is required before entering the system. These features together result in a competitively low cost CO_2 capture system. Among the key variables that influence the performance of these systems and their integration with power plants, the carbonation conversion of the sorbent and the heat requirement at calciner are the most relevant. Both variables are mainly influenced by CaO/CO_2 ratio and make-up flow of solids. New sorbents are under development to reduce the decay of their carbonation conversion with cycles. The aim of this study is to assess the competitiveness of new limestones with enhanced sorption behaviour applied to carbonation/calcination cycle integrated with a power plant, compared to raw limestone. The existence of an upper limit for the maximum average capture capacity of CaO has been considered. Above this limit, improving sorbent capture capacity does not lead to the corresponding increase in capture efficiency and, thus, reduction of CO_2 avoided cost is not observed. Simulations calculate the maximum price for enhanced sorbents to achieve a reduction in CO_2 removal cost under different process conditions (solid circulation and make-up flow). The present study may be used as an assessment tool of new sorbents to understand what prices would be competitive compare with raw limestone in the CO_2 looping capture systems.

10/00676 Effect of heat recirculation on the self-sustained catalytic combustion of propane/air mixtures in a quartz reactor

Scarpa, A. *et al. Combustion and Flame*, 2009, 156, (5), 947–953.

The self-sustained catalytic combustion of propane is experimentally studied in a two-pass, quartz heat-recirculation reactor (HRR) and compared to that in a no (heat) recirculation reactor (NRR). Structured monolithic reactors with $Pt/\gamma\text{-}Al_2O_3$, $LaMnO_3/\gamma\text{-}Al_2O_3$, and Pt doped perovskite catalysts have been compared in the HRR and NRR configurations. Heat recirculation enhances combustion stability, by widening the operating window of self-sustained operation, and changes the mode of stability loss from blowout to extinction. It is found that thermal shields (upstream and downstream of the monolith) play no role in the stability of a HRR but increase the stability of a NRR. The stability of a HRR follows this trend: $Pt/\gamma\text{-}Al_2O_3$ > doped perovskite > $LaMnO_3/\gamma\text{-}Al_2O_3$. Finally, a higher cell density monolith enlarges the operating window of self-sustained combustion, and allows further increase of the power density of the process.

10/00677 Energy valorization of industrial biomass: using a batch frying process for sewage sludge

Romdhana, M. H. *et al. Bioresource Technology*, 2009, 100, (15), 3740–3744.

This paper studies the energy valorization of sewage sludge using a batch fry-drying process. Drying processes was carried out by emerging the cylindrical samples of the sewage sludge in the preheated recycled cooking oil. Experimental frying curves for different conditions were determined. Calorific values for the fried sewage sludge were hence determined to be around 24 MJ kg^{-1}, showing the auto-combustion potential of the fried sludge. A one-dimensional model allowing for the prediction of the water removal during frying was developed. Another water replacement model for oil intake in the fried sewage sludge was also developed. Typical frying curves were obtained and validated against the experimental data.

10/00678 Flow simulation in an electrostatic precipitator of a thermal power plant

Haque, S. M. E. *et al. Applied Thermal Engineering*, 2009, 29, (10), 2037–2042.

The performance of electrostatic precipitator (ESP) is significantly affected by its complex flow distribution arising as a result of its complex inside geometry. In the present study the gas flow through an ESP used at a local thermal power plant is modelled numerically using computational fluid dynamics (CFD) technique to gain an insight into the flow behaviour inside the ESP. CFD code FLUENT is used to carry out the computations. Numerical calculations for the gas flow are carried out by solving the Reynolds-averaged Navier–Stokes equations coupled with the k–ε turbulence model equations. The results of the simulation are discussed and compared with on-site measured data supplied by the power plant. The predicted results show a reasonable agreement with the measured data. The model developed is a novel tool for the thermal power plant to predict the effect of possible modifications made to the ESP design on the flow pattern.

10/00679 High-performance control of a three-phase voltage-source converter including feedforward compensation of the estimated load current

León, A. E. *et al. Energy Conversion and Management*, 2009, 50, (8), 2000–2008.

In this paper a new control strategy for voltage-source converters is introduced. The proposed strategy consists of a non-linear feedback controller based on feedback linearization plus a feedforward compensation of the estimated load current. In this study an energy function and the direct-axis current are considered as outputs, in order to avoid the internal dynamics. In this way, a full linearization is obtained via non-linear transformation and feedback. An estimate of the load current is feedforwarded to improve the performance of the whole system and to diminish the capacitor size. This estimation allows to obtain a more rugged and cheaper implementation. The estimate is calculated by using a non-linear reduced-order observer. The proposal is validated through different tests. These tests include performance in presence of switching frequency, measurement filters delays, parameters uncertainties and disturbances in the input voltage.

10/00680 Hydrodynamics and energy consumption studies in a three-phase liquid circulating three-phase fluid bed contactor

Rusumdar, A. J. *et al. Experimental Thermal and Fluid Science*, 2009, 33, (5), 791–796.

The hydrodynamics and energy consumption have been studied in a cold flow, bubbling and turbulent, pressurized gas–liquid–solid three-phase fluidized bed (0.15 m ID × 1 m height) with concurrent gas–liquid up flow is proposed with the intention of increasing the gas hold up. The hydrodynamic behaviour is described and characterised by some specific gas and liquid velocities. Particles are easily fluidized and can be uniformly distributed over the whole height of the column. The effect of parameters like liquid flow rate, gas flow rate, particle loading, particle size, and solid density on gas hold up and effect of gas flow rate, solid density and particle size on solid hold up, energy consumption and minimum fluidization velocity has been studied. At the elevated pressures a superior method for better prediction of minimum fluidization velocity and terminal settling velocities has been adopted. The results have been interpreted with Bernoulli's theorem and Richardson–Zaki equation. Based on the assumption of the gas and liquid as a pretend fluid, a simplification has been made to predict the particle terminal settling velocities. The Richardson–Zaki parameter n' was compared with Renzo's results. A correlation has been proposed with the experimental results for the three-phase fluidization.

10/00681 Increased use of district heating in industrial processes – impacts on heat load duration

Difs, K. *et al. Applied Energy*, 2009, 86, (11), 2327–2334.

Current knowledge of the potential for an increased use of industrial district heating (DH) due to conversions of industrial processes to DH is limited. In this paper, a method for heat load analysis (MeHLA) for exploring industrial DH conversions has been developed. This method can be a helpful tool for analysing the impact different industrial processes have on the local DH system, when processes that utilize electricity and other fuels, convert to utilizing DH. Heat loads for different types of industries and processes are analysed according to characteristics such as temperature levels and time-dependency. MeHLA has been used to analyse 34 Swedish industries and the method demonstrates how conversion of industrial processes to DH can result in heat load duration curves that are less outdoor temperature-dependent and more evenly distributed over the year. An evenly distributed heat load curve can result in increased annual operating time for base load DH plants such as cogeneration plants, leading to increased electricity generation. In addition to the positive effects for the DH load duration curve, the conversions to DH can also lead to an 11% reduction in the use of electricity, a 40% reduction in the use of fossil fuels and a total energy end-use saving of 6% in the studied industries. Converting the industrial processes to DH will also lead to a potential reduction of the global carbon dioxide emissions by 112,000 tonnes per year.

10/00682 Indicators for industrial energy efficiency in India

Gielen, D. and Taylor, P. *Energy*, 2009, 34, (8), 962–969.

India accounts for 4.5% of industrial energy use worldwide. This share is projected to increase as the economy expands rapidly. The level of industrial energy efficiency in India varies widely. Certain sectors, such as cement, are relatively efficient, while others, such as pulp and paper, are relatively inefficient. Future energy efficiency efforts should focus on direct reduced iron, pulp and paper and small-scale cement kilns because the potentials for improvement are important in both percentage and absolute terms. Under business as usual, industrial energy use is projected to rise faster than total final energy use. A strong focus on energy efficiency can reduce this growth, but CO_2 emissions will still rise substantially. If more substantial CO_2 emissions reductions are to be achieved then energy efficiency will need to be combined with measures that reduce the carbon intensity of the industrial fuel mix.

10/00683 Influence of calcination conditions on carrying capacity of CaO-based sorbent in CO_2 looping cycles

Manovic, V. *et al. Fuel*, 2009, 88, (10), 1893–1990.

his study examines the loss of sorbent activity caused by sintering under realistic CO_2 capture cycle conditions. The samples tested here included two limestones: Havelock limestone from Canada (New Brunswick) and a Polish (Upper Silesia) limestone (Katowice). Samples were prepared both in a thermogravimetric analyser (TGA) and a tube furnace (TF). Two calcination conditions were employed: in N_2 at lower temperature; and in CO_2 at high temperature. The samples obtained were observed with a scanning electron microscope (SEM) and surface compositions of the resulting materials were analysed by the energy dispersive X-ray (EDX) method. The quantitative influence of calcination conditions was examined by nitrogen adsorption/desorption tests, gas displacement pycnometry and powder displacement pycnometry; BET surface areas, BJH pore volume distributions, skeletal densities and envelope densities were determined. The SEM images showed noticeably larger CaO sub-grains were produced by calcination in CO_2 during numerous cycles than those seen with calcination in nitrogen. The EDX elemental analyses showed a strong influence of impurities on local melting at the sorbent particle surface, which became more pronounced at higher temperature. Results of BET/BJH testing clearly support these findings on the effect of calcination/cycling conditions on sorbent morphology. Envelope density measurements showed that particles displayed densification upon cycling and that particles calcined under CO_2 showed greater densification than those calcined under N_2. Interestingly, the Katowice limestone calcined/cycled at higher temperature in CO_2 showed an increase of activity for cycles involving calcination under N_2 in the TGA. These results clearly demonstrate that, in future development of CaO-based CO_2 looping cycle technology, more attention should be paid to loss of sorbent activity caused by realistic calcination conditions and the presence of impurities originating from fuel ash and/or limestone.

10/00684 Joining semi-closed gas turbine cycle and tri-reforming: SCGT-TRIREF as a proposal for low CO_2 emissions powerplants

Fiaschi, D. and Baldini, A. *Energy Conversion and Management*, 2009, 50, (8), 2083–2097.

Methane conversion to a rich H_2 fuel by reforming reactions is a largely applied industrial process. Recently, it has been considered for applications combined to gas turbine powerplants, as a mean for (I) chemical recuperation (i.e. chemical looping CRGT) and (II) decarbonizing the primary fuel and making the related power cycle a low CO_2 releaser. The possibility of enhancing methane conversion by the addition of CO_2 to the steam reactant flow (i.e. tri-reforming) has been assessed and showed interesting results. When dealing with gas turbines, the possibility of applying tri-reforming is related to the availability of some CO_2 into the fluegas going to the reformer. This happens in semi-closed gas turbine cycles (SCGT), where the fluegas has a typical 14–15% CO_2 mass content. The possibility of joining CRGT and SCGT technologies to improve methane reforming and propose an innovative, low CO_2 emissions gas turbine cycle was assessed here. One of the key issues of this joining is also the possibility of greatly reduce the external water consumption due to the reforming, as the SCGT is a water producer cycle. The SCGT-TRIREF cycle is an SCGT cycle where fuel tri-reforming is applied. The steam due to the reformer is generated by the vaporization of the condensed water coming out from the fluegas condensing heat exchanger, upstream the main compressor, where the exhausts are cooled down and partially recirculated. The heat due to the steam generation is recuperated from the turbine exhausts cooling. The reforming process is partially sustained by the heat recovered from the turbine exhausts (which generates superheated steam) and partially by the auto thermal reactions of methane with fresh air, coming from the compressor (i.e. partial combustion). The effect of CO_2 on methane reforming (tri-reforming effect) increases with decreasing steam/methane ratio: at very low values, around 30% of methane is converted by reactions with CO_2. At high values of steam/methane ratio, the steam reforming reactions are dominant and only a marginal fraction of methane is interested to tri-reforming. Under optimized conditions, which can be reached at relatively high pressure ratios (25–30), the power cycle showed a potential efficiency around 46% and specific work at 550 kJ/kg level. When the amine CO_2 capture is applied, the specific CO_2 emissions range between 45 and 55 g_{CO2}/kW h.

10/00685 Multi-criteria evaluation of hydrogen and natural gas fuelled power plant technologies

Pilavachi, P. A. *et al. Applied Thermal Engineering*, 2009, 29, (11–12), 2228–2234.

This paper evaluates nine types of electrical energy generation options with regard to seven criteria. The options use natural gas or hydrogen as a fuel. The analytic hierarchy process was used to perform the evaluation, which allows decision-making when single or multiple criteria are considered. The options that were evaluated are the hydrogen combustion turbine, the hydrogen internal combustion engine, the hydrogen fuelled phosphoric acid fuel cell, the hydrogen fuelled solid oxide fuel cell, the natural gas fuelled phosphoric acid fuel cell, the natural gas fuelled solid oxide fuel cell, the natural gas turbine, the natural gas combined cycle and the natural gas internal combustion engine. The criteria used for the evaluation are CO_2 emissions, NO_X emissions, efficiency, capital cost, operation and maintenance costs, service life and produced electricity cost. A total of 19 scenarios were studied. In 15 of these scenarios, the hydrogen turbine ranked first and proved to be the most preferred electricity production technology. However since the hydrogen combustion turbine is still under research, the most preferred power generation technology which is available nowadays proved to be the natural gas combined cycle which ranked first in five scenarios and second in eight. The last in ranking electricity production technology proved to be the natural gas fuelled phosphoric acid fuel cell, which ranked in the last position in 13 scenarios.

10/00686 Numerical investigation of hot air recirculation of air-cooled condensers at a large power plant

Liu, P. *et al. Applied Thermal Engineering*, 2009, 29, (10), 1927–1934.

In order to minimize the hot air recirculation (HAR) to ensure normal operation of the air-cooled condensers (ACC) system, the hot air recirculation phenomenon and its dependence on ambient winds are numerically simulated by using the computational fluid dynamics code, FLUENT. Under the constant ambient temperature, the effects of different wind speed and wind direction on the HAR are qualitatively considered by applying the concept of the hot recirculation rate (HRR). The mechanism of occurrence of hot air recirculation are presented and analysed. It was found that when considering about the existing and normally operating power plants, the HAR is more sensitive to wind direction and wind speed. Based on the above results, two improved measures increasing the wind-wall height and accelerating the rotational speed of the fans near the edge of the ACC platform are developed to effectively reduce the hot air recirculation.

10/00687 On-line monitoring the performance of coal-fired power unit: a method based on support vector machine

Cai, J. *et al. Applied Thermal Engineering*, 2009, 29, (11–12), 2308–2319.

This paper introduces a novel on-line monitoring performance method of coal-fired power unit. A support vector machine (SVM) is used to predict the unburned carbon content of fly ash in the boiler and the exhaust steam enthalpy in turbine, which are two difficulties in the real time economic performance calculation model in coal-fired power plant. Comparison between the output of SVM modelling and the experimental data shows a good agreement, and compared with conventional artificial neural network techniques, SVM can achieve better accuracy and generalization. This presented monitoring method is proven by the results of application cases in a practical coal-fired power plant.

10/00688 Reducing CO_2 emissions for an IGCC power generation system: effect of variations in gasifier and system operating conditions

Gnanapragasam, N. *et al. Energy Conversion and Management*, 2009, 50, (8), 1915–1923.

In an integrated gasification combined cycle (IGCC) power generation system, the effectiveness of the gasification process significantly affects system performance while the optimization of system operating conditions is essential for improved utilization of the syngas. The benefits to the gasifier and IGCC system are currently investigated through a sensitivity analysis of gasifier and system operating conditions. In the analysis, the following are varied: (i) thermal operating conditions of the IGCC system, (ii) inlet conditions of the gasifier (steam–coal, oxygen–coal ratios) and (iii) fuel (four solid fuels are considered). The thermal operating conditions used here are variations in the inlet temperatures at three locations within the IGCC system (the gas turbine combustion chamber, the gas turbine and the heat recovery steam generator). The operating effectiveness of the gasifier and the IGCC system are analysed considering fuel utilization based on estimates of relative and specific net work output rates, combined cycle efficiency and CO_2 emissions. The analysis is discussed on the basis of the increase in gasification of the fixed carbon in the source fuel (i.e. from partial to full gasification) thus comparing the proposed IGCC system for the entire range of gasification. Results from the analysis suggest that increasing gasification: (i) increases efficiency, (ii) marginally decreases net work output rate, (iii) reduces coal consumption, thus reducing CO_2 emissions. Char combustion in the supplementary firing chamber helps to reduce CO_2 emissions for the same work output. Partial gasification above 70% of fixed carbon yields lower CO_2 emissions for all conditions discussed. Increasing the compressed air inlet temperature to the gas cycle increases CO_2 emissions. A higher steam-to-coal ratio yields lower specific CO_2 emissions and a lower oxygen-to-coal ratio yields lower CO_2 emissions. Higher carbon content in the fuel yields higher CO_2 emissions, especially at above 60% gasification.

10/00689 The economics of reburning with cattle manure-based biomass in existing coal-fired power plants for NO_x and CO_2 emissions control

Carlin, N. T. *et al. Biomass and Bioenergy*, 2009, 33, (9), 1139–1157.

Coal plants that reburn with cattle biomass (CB) can reduce CO_2 emissions and save on coal purchasing costs while reducing NO_x emissions by 60–90% beyond levels achieved by primary NO_x controllers. Reductions from reburning coal with CB are comparable to those obtained by other secondary NO_x technologies such as selective catalytic reduction (SCR). The objective of this study is to model potential emission and economic savings from reburning coal with CB and compare those savings against competing technologies. A spreadsheet computer program was developed to model capital, operation, and maintenance costs for CB reburning, SCR, and selective non-catalytic reduction (SNCR). A base case run of the economics model, showed that a CB reburn system retrofitted on an existing 500 MW_e coal plant would have a net present worth of −\$80.8 million. Comparatively, an SCR system under the same base case input parameters would have a net present worth of +\$3.87 million. The greatest increase in overall cost for CB reburning was found to come from biomass drying and processing operations. The profitability of a CB reburning system retrofit on an existing coal-fired plant improved with higher coal prices and higher valued NO_x emission credits. Future CO_2 taxes of \$25 $tonne^{-1}$ could make CB reburning as economically feasible as SCR. Biomass transport distances and the unavailability of suitable, low-ash CB may require future research to concentrate on smaller capacity coal-fired units between 50 and 300 MW_e.

10 SPACE HEATING AND COOLING/HEAT PUMPS

10/00690 A ‘drop-in’ refrigerant R431A for replacing HCFC22 in residential air-conditioners and heat pumps

Park, K.-J. *et al. Energy Conversion and Management*, 2009, 50, (7), 1671–1675.

In this study, thermodynamic performance of R431A and HCFC22 is measured in a heat pump bench tester under air-conditioning and heat pumping conditions. R431A is an near azeotropic mixture composed of 71% propane and 29% HFC152a by mass. It has no ozone depletion potential and low greenhouse warming potential of 43. R431A also offers a similar vapour pressure to that of HCFC22 for possible ‘drop-in’ replacement. Test results showed that the coefficient of performance of R431A is 3.5–3.8% higher than that of HCFC22 while the capacity of R431A is very similar to that of HCFC22 under both conditions. The compressor discharge temperature of R431A is 21.1–27.3 °C lower than that of HCFC22 while the amount of charge for R431A is 50.0–51.9% lower than that of HCFC22 due to its low density. Overall, R431A is a good long term environmentally friendly 'drop-in' alternative to replace HCFC22 in residential air-conditioners and heat pumps due to its excellent thermodynamic and environmental properties.

10/00691 A 3D CAD-based simulation tool for prediction and evaluation of the thermal improvement effect of passive cooling walls in the developed urban locations

He, J. and Hoyano, A. *Solar Energy*, 2009, 83, (7), 1064–1075.

As a passive cooling strategy aimed at controlling increased surface temperatures and creating cooler urban environments, the authors have developed a passive cooling wall (PCW) constructed of moist void bricks that are capable of absorbing water and which allow wind penetration, thus reducing their surface temperatures by means of water evaporation. Passive cooling effects, such as solar shading, radiation cooling and ventilation cooling can be enhanced by incorporating PCWs into the design of outdoor or semi-enclosed spaces in parks, pedestrian areas and residential courtyards. The purpose of the present paper is to detail the development of a 3D CAD-based simulation tool that can be used to predict and evaluate the thermal improvement effect in urban locations where PCW installation is under consideration. Measurement results for the surface reduction effect of a PCW are introduced in the first part of the paper. In the second part, thermal modelling of a PCW is proposed based on analysis results of experimental data. Following that, a comparison study that integrates the proposed thermal modelling was conducted to validate the simulation method. In order to demonstrate the applicability of the developed simulation tool, a case study was then performed to predict and evaluate the thermal improvement effect at an actual urban location where PCWs were installed. Simulations were performed by modelling the construction location in two scenarios; one where the PCWs were composed of dry bricks, and another where the bricks were wet. The results show that, in terms of surface temperature and mean radiant temperature (MRT), this simulation tool can provide quantitative predictions and evaluations of thermal improvements resulting from the installation of PCWs.

10/00692 A fault detection technique for air-source heat pump water chiller/heaters

Chen, Y. and Lan, L. *Energy and Buildings*, 2009, 41, (8), 881–887.

This paper describes a fault detection method and system to detect the faults in air-source heat pump water chiller/heaters. Principal component analysis (PCA) approach is used to extract the correlation of variables in heat pump unit and reduce the dimension of measured data. A PCA model is built to determine the thresholds of statistics and calculate square prediction errors of new observations, which are used to check if a fault occurs in heat pump unit. The fault detection system consists of a PCA-based fault detection code, a backpack computer, a digital logger and eight easy-to-install temperature sensors. A real air-source heat pump water chiller/heater for the air-conditioning system of an office building provides the realistic test platform for the validation of fault detection method. The measured data from the heat pump unit under normal condition shows that the PCA model can capture the major correlation and variance among the test variables. Two levels of artificial condenser fouling fault are successfully detected. The results show that the PCA-based fault detection method is applicable and effective for air-source heat pump water chiller/heater.

10/00693 A study on optimum insulation thicknesses of external walls in hot summer and cold winter zone of China

Yu, J. *et al. Applied Energy*, 2009, 86, (11), 2520–2529.

The employ of thermal insulation is one of the most effective ways of building energy conservation for cooling and heating. Therefore, the selection of a proper insulation material and the determination of optimum insulation thickness are particularly vital. Four typical cities of Shanghai, Changsha, Shaoguan and Chengdu are selected to represent A, B, C and D subzone of hot summer and cold winter zone in China, respectively. The optimum thicknesses of five insulation materials including expanded polystyrene, extruded polystyrene, foamed polyurethane, perlite and foamed polyvinyl chloride are calculated with a typical residential wall using solar-air cooling and heating degree-days analysis and P_1–P_2 economic model. And then, life cycle total costs, life cycle savings and payback periods are calculated based on life cycle cost analysis. Considering different orientations, surface colours, insulation materials and climates, optimum thicknesses of the five insulations vary from 0.053 to 0.236 m, and the payback periods vary from 1.9 to 4.7 years over a lifetime of 20 years. The maximum life cycle savings are 54.4 \$/m^2 in Shanghai, 54.8 \$/m^2 in Changsha and 41.5 \$/m^2 in Shaoguan (with a deep-coloured northeast wall), and 39.0 \$/m^2 in Chengdu (with a light-coloured northwest wall). Finally, an approach to analyse economical efficiency of insulation materials is developed, result shows that expanded polystyrene is the most economic insulation material of the five because of the highest life cycle saving and lowest payback period.

10/00694 Adaptive neuro-fuzzy based inferential sensor model for estimating the average air temperature in space heating systems

Jassar, S. *et al. Building and Environment*, 2009, 44, (8), 1609–1616.

Heating systems are conventionally controlled by open-loop control systems because of the absence of practical methods for estimating average air temperature in the built environment. To address this, an inferential sensor model, based on adaptive neuro-fuzzy inference system modelling, for estimating the average air temperature in multi-zone space heating systems was developed. This modelling technique has the advantage of expert knowledge of fuzzy inference systems and learning capability of artificial neural networks. A hybrid learning algorithm, which combines the least-square method and the back-propagation algorithm, was used to identify the parameters of the network. This paper describes an adaptive network based inferential sensor that can be used to design closed-loop control for space heating systems. The research aims to improve the overall performance of heating systems, in terms of energy efficiency and thermal comfort. The average air temperature results estimated by using the developed model are strongly in agreement with the experimental results.

10/00695 Analysis of heat transfer and frost layer formation on a cryogenic tank wall exposed to the humid atmospheric air

Kim, K.-H. *et al. Applied Thermal Engineering*, 2009, 29, (10), 2072–2079.

In this paper heat transfer characteristics and frost layer formation are investigated numerically on the surface of a cryogenic oxidizer tank for a liquid propulsion rocket, where a frost layer could be a significant factor in maintaining oxidizer temperature within a required range. Frost formation is modelled by considering mass diffusion of water vapour in the air into the frost layer and various heat transfer modes such as natural and forced convection, latent heat, solar radiation of short wavelength, and ambient radiation of long wavelength. Computational results are first compared with the available measurements and show favourable agreement on thickness and effective thermal conductivity of the frost layer. In the case of the cryogenic tank, a series of parametric studies is presented in order to examine the effects of important parameters such as temperature and wind speed of ambient air, air humidity, and tank wall temperature on the frost layer formation and the amount of heat transfer into the tank. It is found that the heat transfer by solar radiation is significant and also that heat transfer strongly depends on air humidity, ambient air temperature, and wind speed but not tank wall temperature.

10/00696 Application of multicriteria analysis in designing HVAC systems

Avgelis, A. and Papadopoulos, A. M. *Energy and Buildings*, 2009, 41, (7), 774–780.

The present paper discusses a study which aims to develop a method for choosing and managing in the best possible way heating, ventilating and air conditioning (HVAC) systems in new and existing buildings. The method utilizes a combination of two analysis' tools, the multi-criteria decision-making and the building simulation towards the direction of a holistic assessment of HVAC systems. In order to evaluate the method, a series of HVAC systems are considered for installing in an office building and the multicriteria method Electre III is applied for their selection. The results show that the proposed model allows the classification of alternative technical solutions concerning the HVAC's design, taking into consideration economic, energy and environmental criteria as well as criteria of users' satisfaction. Finally, the study also indicates that when applying the sustainability concept in the building sector, and especially in the HVAC systems, this should concern the overall socioeconomic costs.

10/00697 CFD study of the thermal environment in an air-conditioned train station building

Li, Q. *et al. Building and Environment*, 2009, 44, (7), 1452–1465.

This study used the computational fluid dynamics method to evaluate the indoor thermal environment of an air-conditioned train station building under three types of air-conditioning design schemes. The impacts of air-conditioning design parameters such as supply air temperature, velocity, altitude and angle of incidence were also investigated. The numerical results showed that if the waiting hall and entrance hall of the train station building were connected to each other and served with the cooling air respectively, when the cooling loads in the two halls were fixed and air-conditioning systems were designed properly, altering largely the cooling air supply scheme in the waiting hall while keeping the cooling air supply scheme in the entrance hall unchanged would have significant effects on the air distribution and thermal comfort in the occupied region of the waiting hall but may have some minor effects on those in the occupied region of the entrance hall. The uniformities of velocity and temperature distributions in the occupied region of waiting hall were satisfactory when side supply scheme was applied. Changing supply air temperature, velocity, altitude and angle of incidence would yield great effects on the thermal environment in the train station building. For the stratified air-conditioning design in the train station building, in order to obtain the satisfactory thermal comfort in the occupied region, the mid-height of the building was found to be a good position for the cooling air supply and the supply angle of 0° from the horizontal could be recommendable. The results also indicated that analysing the effects of air-conditioning design parameters on the building environment with computational fluid dynamics was an effective method to find the way to optimize the air-conditioning design scheme.

10/00698 Construction and initial operation of the combined solar thermal and electric desiccant cooling system

Enteria, N. *et al. Solar Energy*, 2009, 83, (8), 1300–1311.

This study considers the constructed combined solar thermal and electric desiccant cooling system – its initial operation and operational procedures. The system, as designed, can be operated during nighttime and daytime. The nighttime operation is for thermal energy storage using the auxiliary electric heater, while the daytime operation is for solar energy collection and desiccant cooling. Ongoing experimental evaluation is being undertaken to observe and determine the long-term performance of the system.

10/00699 Design and experimental performance of a PV ice-maker without battery

Axaopoulos, P. J. and Theodoridis, M. P. *Solar Energy*, 2009, 83, (8), 1360–1369.

This paper presents a solar photovoltaic powered ice-maker which operates without the use of batteries and is therefore environmentally friendly and may be used in truly autonomous applications in remote areas. The successful operation of the refrigeration compressors by the photovoltaic panels is ensured by the use of a novel concept dedicated controller, which provides easy startup, maximum power tracking and power management for the four compressors of the system. The prototype results have shown very good ice-making capability and reliable operation as well as a great improvement in the startup characteristics of the compressors, which remain operational even during days with low solar irradiation and operate with improved utilization of the available photovoltaic power.

10/00700 Determination of optimum working conditions R22 and R404A refrigerant mixtures in heat-pumps using Taguchi method

Comakli, K. *et al. Applied Energy*, 2009, 86, (11), 2451–2458.

In this study, refrigerants R22 and R404A five of their binary mixtures which contain about 0%, 25%, 50%, 75% and 100% mass fractions of R404A were tested. It is investigated experimentally the effects of gas mixture rate, evaporator air inlet temperature (from 24 to 32 °C), evaporator air mass flow rate (from 0.58 to 0.74 kg/s), condenser air inlet temperature (from 22 to 34 °C) and condenser air mass flow rate (from 0.57 to 0.73 kg/s) on the coefficient of performance and exergetic efficiency values of vapour compression heat-pump systems. To determine the effect of the chosen parameters on the system and optimum working conditions, an experimental design method suggested elsewhere was used. In this study, it was observed that the most effective parameters are found to be the condenser air inlet temperature for coefficient of performance and exergetic efficiency.

10/00701 Development and experimental validation of a high-temperature heat pump for heat recovery and building heating

Wang, K. *et al. Energy and Buildings*, 2009, 41, (7), 732–737.

The performance of a high-temperature heat pump unit using geothermal water for heat recovery in buildings is experimentally evaluated. The unit consists of a twin-screw refrigeration compressor, a condenser, an evaporator and an oil cooling system. The effect of the cooled oil temperature on the performance of the heat pump unit is experimentally investigated. Results show that the unit stably produces outlet hot water at a constant temperature of 85 °C and performs well in a wide range of high-temperature conditions with a high energy efficiency ratio. The results also indicate that the key to improving the performance of a high-temperature heat pump unit often depend on the selection of proper cooled oil temperature. The optimum cooled oil temperature is 50–65 °C when the condensing temperature is above 70 °C. At these temperatures, the oil cooling system can increase the energy efficiency ratio of the heat pump by 6.3%.

10/00702 Development of small-scale and micro-scale biomass-fuelled CHP systems – a literature review

Dong, L. *et al. Applied Thermal Engineering*, 2009, 29, (11–12), 2119–2126.

A review is carried out on the development of small- and micro-scale biomass-fuelled combined heat and power (CHP) systems. Discussions have been concentrated on the current application of Organic Rankine Cycle (ORC) in small- and micro-scale biomass-fuelled CHP systems. Comparisons have been made between ORC and other technologies such as biomass gasification and micro-turbine based biomass-fuelled CHP systems. The advantages and disadvantages of each technology have been discussed. Recommendations have been made on the future development of small- and micro-scale biomass-fuelled CHP.

10/00703 Effect of linear and non-linear components in the temperature dependences of thermoelectric properties on the energy conversion efficiency

Yamashita, O. *Energy Conversion and Management*, 2009, 50, (8), 1968–1975.

The new thermal rate equations were built up by taking the linear and non-linear components in the temperature dependences of the Seebeck coefficient α, the electrical resistivity ρ and thermal conductivity κ of a thermoelectric (TE) material into the thermal rate equations on the assumption that their temperature dependences are expressed by a quadratic function of temperature T. The energy conversion efficiency η for a single TE element was formulated using the new thermal rate ones proposed here. By applying it to the high-performance half-Heusler compound, the non-linear component in the temperature dependence of α among those of the TE properties has the greatest effect on η, so that η/η_0 was increased by 11% under the condition of $T = 510\,\mathrm{K}$ and $\Delta T = 440\,\mathrm{K}$, where α_0 is a well-known conventional energy conversion efficiency. It was thus found that the temperature dependences of TE properties have a significant influence on η. When one evaluates the accurate achievement rate of η_{exp} obtained experimentally for a TE generator, therefore, η_{exp} should be compared with η_{the} estimated from the theoretical expression proposed here, not with η_0, particularly when there is a strong non-linearity in the temperature dependence of TE properties.

10/00704 Energy and exergy analysis of vapor compression refrigeration system using pure hydrocarbon refrigerants

Bayrakçi, H. C. and Özgür, A. E. *International Journal of Energy Research*, 2009, 33, (12), 1070–1075.

This study presents a comparison of energetic and exergetic performance of a vapour compression refrigeration system using pure hydrocarbon (HC) refrigerants. In this study, four different pure HCs propane (R290), butane (R600), isobutane (R600a) and isopentane (R1270) are used in theoretical analysis. R22 and R134a are also used in the analysis. For the analysis, EES package program was used for solving thermodynamic equations of the refrigerants. Results have been presented graphically. According to results, differences of coefficient of cooling performance values of these refrigerants are quite small. Energetic and exergetic efficiency values obtained with R1270 and R600 are higher than R600a and R290.

10/00705 Evaporation heat transfer enhancement of R-134a flowing inside smooth and micro-fin tubes using the electrohydrodynamic technique

Posew, K. *et al. Energy Conversion and Management*, 2009, 50, (7), 1851–1861.

Heat transfer enhancement using the electrohydrodynamic (EHD) technique during evaporation inside horizontal smooth and micro-fin tubes is experimentally investigated. The test section is a counter-flow concentric tube-in-tube heat exchanger with R-134a flowing inside inner tube and heating water flowing in the annulus. Smooth and micro-fin inner tubes are used as test section. The outer diameter and length of inner tubes are 9.52 mm and 2.50 m, respectively. The outer tube is a smooth copper tube having inner diameter of 27 mm. The electrode is made from stainless steel rod of 1.47 mm diameter. Experiments are performed at average saturation temperatures ranging between 10 and 20 °C, heat fluxes ranging between 10 and 20 kW/m^2 at mass flux of 400 kg/m^2 s and applied voltage of 2.5 kV. The maximum heat transfer enhancement ratios are 1.25 and 1.15 for smooth tube and micro-fin tube, respectively. New correlations based on the data gathered during this work for predicting the evaporation heat transfer coefficient in smooth tube and micro-fin tube are proposed for practical applications.

10/00706 Experimental and numerical investigation on air-side performance of fin-and-tube heat exchangers with various fin patterns

Tang, L. H. *et al. Experimental Thermal and Fluid Science*, 2009, 33, (5), 818–827.

Air-side heat transfer and friction characteristics of five kinds of fin-and-tube heat exchangers, with the number of tube rows ($N = 12$) and the diameter of tubes ($D_o = 18$ mm), have been experimentally investigated. The test samples consist of five types of fin configurations: crimped spiral fin, plain fin, slit fin, fin with delta-wing longitudinal vortex generators (VGs) and mixed fin with front 6-row VG fin and rear 6-row slit fin. The heat transfer and friction factor correlations for different types of heat exchangers were obtained with the Reynolds numbers ranging from 4000 to 10,000. It was found that crimped spiral fin provides higher heat transfer and pressure drop than the other four fins. The air-side performance of heat exchangers with the above five fins has been evaluated under three sets of criteria and it was shown that the heat exchanger with mixed fin (front VG fin and rear slit fin) has better performance than that with fin with delta-wing VGs, and the slit fin offers best heat transfer performance at high Reynolds numbers. Based on the correlations of numerical data, genetic algorithm optimization was carried out, and the optimization results indicated that the increase of VG attack angle or length, or decrease of VG height may enhance the performance of VG fin. The heat transfer performances for optimized VG fin and slit fin at hand have been compared with numerical method.

10/00707 Experimental investigation of plastic finned-tube heat exchangers, with emphasis on material thermal conductivity

Chen, L. *et al. Experimental Thermal and Fluid Science*, 2009, 33, (5), 922–928.

In this paper, two modified types of polypropylene (PP) with high thermal conductivity up to 2.3 W/m K and 16.5 W/m K are used to manufacture the finned-tube heat exchangers, which are prospected to be used in liquid desiccant air conditioning, heat recovery, water source heat pump, sea water desalination, etc. A third plastic heat exchanger is also manufactured with ordinary PP for validation and comparison. Experiments are carried out to determine the thermal performance of the plastic heat exchangers. It is found that the plastic finned-tube heat exchanger with thermal conductivity of 16.5 W/m K can achieve overall heat transfer coefficient of 34 W/m^2 K. The experimental results are compared with calculation and they agree well with each other. Finally, the effect of material thermal conductivity on heat exchanger thermal performance is studied in detail. The results show that there is a threshold value of material thermal conductivity. Below this value improving thermal conductivity can considerably improve the heat exchanger performance while over this value improving thermal conductivity contributes very little to performance enhancement. For the finned-tube heat exchanger designed in this paper, when the plastic thermal conductivity can reach over 15 W/m K, it can achieve more than 95% of the titanium heat exchanger performance and 84% of the aluminium or copper heat exchanger performance with the same dimension.

10/00708 Feasibility study on power ultrasound for regeneration of silica gel – a potential desiccant used in air-conditioning system

Yao, Y. *et al. Applied Energy*, 2009, 86, (11), 2394–2400.

A new regeneration method using power ultrasound was put forward to overcome the limitations of silica gel in air-conditioning applications, such as high regeneration temperature and low regeneration efficiency. The technical feasibility of the new method was validated experimentally and demonstrated in detail from different sides. The experiments were performed under different regeneration temperatures, i.e. 45 °C, 55 °C, 65 °C and 75 °C. The power and frequency of ultrasound applied in this experimental study was set as 40 W and 26 kHz, respectively. The three indicators, including the regeneration degree (RD), enhanced rate of regeneration (ER) and energy-saving rate (ESR), were suggested to evaluate the effect of power ultrasound in the regeneration. The Crank's diffusion model was used for the calculation of the moisture diffusivity in silica gel, and the Arrhenius equation for the determination of energy activation of moisture desorption on silica gel. The analysis results prove that the introduction of high-intensity ultrasound to the regeneration of silica gel can help to improve the regeneration efficiency and reduce regeneration energy. The benefits should owe to the special 'heating effect' and 'micro-vibration effect' caused by power ultrasound that can enhance the moisture diffusivity in silica gel and lower the activation energy of moisture desorption on silica gel.

10/00709 Forced convection and entropy generation from elliptic tubes with longitudinal fins

Ibrahim, E. and Moawed, M. *Energy Conversion and Management*, 2009, 50, (8), 1946–1954.

An experimental investigation has been conducted to clarify heat transfer characteristics and entropy generation for individual elliptic tubes with longitudinal fins. The investigated geometrical parameters included the placement of the fins at the front of the tube, at the rear of the tube and at the front and rear of the tube. The experiments have been carried out on the different cases of electrically heated elliptic tubes which are separately installed in a square tunnel. The surface temperature at different cases of elliptic tubes, have been measured. The testing fluid was air and the Reynolds number ranged from about 4.75×10^3 to 3.96×10^4. The analysis of the entropy generation is based on the principle of minimizing the rate of total entropy generation that includes the generation of entropy due to heat transfer and friction forces are presented. The results indicate that the fin position on the elliptic tube has an effect on the results of heat transfer coefficient, friction factor and irreversibility ratio. The correlations of average Nusselt number, friction factor and irreversibility ratio with *Re* are presented.

10/00710 Heat rejection pressure optimization for a carbon dioxide split system: an experimental study

Aprea, C. and Maiorino, A. *Applied Energy*, 2009, 86, (11), 2373–2380.

Recent studies indicate carbon dioxide (R744) as a valid alternative to classical substances such as HFCs used in vapour compression plants. However a transcritical refrigeration cycle is needed because the critical temperature of carbon dioxide is usually near the ambient temperature. Consequently the carbon dioxide refrigerator performances are significantly influenced by the heat rejection pressure. In this paper an experimental investigation on working optimization for a 'split-system' to cool air in residential applications is presented: by varying the heat rejection pressure an optimum working condition has been found at different ambient temperatures. Furthermore a simplified model to predict the optimum heat rejection pressure is shown and a comparison with experimental results is carried out. Both the model validation and the experimental results suggest that the heat rejection pressure optimization is a convenient method to improve the performance of a carbon dioxide split system. Finally an algorithm based on the aforementioned model has been proposed in order to control an electronic back pressure valve by means of a PLC.

10/00711 Heating characteristics of convection reflow ovens

Illés, B. and Harsányi, G. *Applied Thermal Engineering*, 2009, 29, (11–12), 2166–2171.

The inhomogeneous temperature distribution in the reflow oven can cause soldering failures. This study investigates how the construction of a convection reflow oven has an affect on its heating characteristics. In the convection reflow oven itself, the heating capability is mainly dependent on the heat transfer coefficient, which in turn is mostly determined by the gas flow parameters. Therefore, the authors studied how the construction of the reflow oven affects the flow of gas in the oven. The conclusions were then verified with experimental results. During these experiments, temperature changes were measured at different points located around the centre of the processing area in the oven. From this data, the 3D directional characteristics of the heat transfer coefficient were calculated using the heat equation of the investigated reflow oven. These results are important for the effective thermal modelling of the reflow soldering process and are also useful when calibrating and designing reflow ovens. During this work, the latest reflow ovens constructed with the nozzle-matrix blower system were examined.

10/00712 Hygrothermal performance study of an innovative interior thermal insulation system

Pavlík, Z. and Černý, R. *Applied Thermal Engineering*, 2009, 29, (10), 1941–1946.

An innovative interior thermal insulation system on the basis of hydrophilic mineral wool which can serve as an alternative solution to the commonly used systems with water vapour barrier is presented in the paper. At first, the process of materials design is described. Then, the hygrothermal performance of the designed insulation system is tested in the difference climate conditions that correspond to the winter climate in central Europe. In the experiment, the profiles of temperature, relative humidity and liquid moisture content are monitored. Measured temperature profiles demonstrate the proper thermal insulation function of the system. The hygric function can also be considered very good as no water condensation during the whole testing period of five months appears in the insulation layer. Therefore, the basic requirements for the successful application of the system in building practice are met.

10/00713 Improved lumped models for combined convective and radiative cooling of a wall

Tan, Z. *et al. Applied Thermal Engineering*, 2009, 29, (11–12), 2439–2443.

Improved lumped parameter models are developed for the transient heat conduction of a wall subjected to combined convective and radiative cooling. The improved lumped models are obtained through two point Hermite approximations for integrals. It is shown by comparison with numerical solution of the original distributed parameter model that the higher order lumped model ($H_{1,1}/H_{0,0}$ approximation) yields significant improvement of average temperature prediction over the classical lumped model.

10/00714 Incorporating fan control into air-conditioning systems to improve energy efficiency and transient response

Yeh, T. J. *et al. Applied Thermal Engineering*, 2009, 29, (10), 1955–1964.

Modern air-conditioners frequently incorporate variable-speed compressors and variable-opening expansion valves with feedback control to improve performance and power efficiency. Because making the fan speeds adjustable adds flexibility to the control design and thus can lead to further improvements in performance and efficiency, this paper proposes two control algorithms, respectively, incorporating the outdoor fan and the indoor fan as the additional control inputs for air-conditioning systems. Both of the control algorithms are designed based on a low-order, linear model obtained from system identification. The first algorithm, which modulates the outdoor fan speed, can reduce the steady state power consumption if the temperature difference between the condenser and the outdoor environment is controlled properly. The second algorithm, which adds one more degree of freedom to control by modulating the indoor fan speed, can improve the transient response because actuator saturations become less likely to occur. The two control algorithms are implemented on a split-type residential air-conditioner and their respective performance is validated experimentally.

10/00715 Investigation on the thermal performance of different lightweight roofing structures and its effect on space cooling load

Han, J. *et al. Applied Thermal Engineering*, 2009, 29, (11–12), 2491–2499.

The lightweight aluminium standing seam roofing system (LASRS) has been widely used as a building element in the construction of either commercial or governmental buildings, and has been proven to be an economic roofing system. However, little research has been conducted into its thermal performance and the effect of the absorptivity (colour) of its external surface on space cooling load in the hot humid area. This paper aims to investigate the thermal performance of the LASRS. A dynamic model is introduced for analysing the transient heat transfer through the roofs, which was solved by the control volume finite-difference method employing an explicit scheme and validated by measured data. The simulation results show that the heat flux through the roofing system with a polyurethane insulation layer is smaller than that through the lightweight roof with glasswool insulation R1. The space cooling load reduction ratio for light painted envelop could reach about 9.3% compared with black painted one. The cooling load reduction ratio ranges from 1.3% to 9.3% for the roof structure R1 with various surface colour. Therefore, the space cooling load for air conditioning of the building can be considerably reduced (up to 20%) by employing a lightweight roof using polyurethane insulation with white painted surface colour.

10/00716 Lithium bromide absorption machines: pressure drop and mass transfer in solutions conical sheets

Palacios, E. *et al. Energy Conversion and Management*, 2009, 50, (7), 1802–1809.

Adiabatic vapour absorption in conical liquid sheets is studied with a view to use in air conditioning. The sheets consist in a lithium bromide aqueous solution sprayed at mass flow rates ranging from 0.0078 to 0.0116 kg/s (28–42 kg/h). The experimental results show that the deformation rate associated with conical sheet development has a significant effect on absorption, with 60% of the total reached by the time the liquid sheet disintegrates, 4 ms after injection. In the conical sheet configuration, about 150 g of vapour are absorbed per kJ of solution flow work. The vapour absorption rate per chamber absorption volume, in turn, is found to be over 1 g/s l in absorption chambers 75 mm long or less.

10/00717 Locating room air-conditioners at floor level for energy saving in residential buildings

Gao, C. F. *et al. Energy Conversion and Management*, 2009, 50, (8), 2009–2019.

Residential air-conditioning becomes a common feature of daily life. They are typically installed at high level known as ceiling-based system (CAC). With the increasing use of floor-based air-conditioning system in commercial buildings for energy saving, it is proposed in this study to locate a top discharge/front return air-conditioner at floor level to resemble a floor-based air-conditioning system (FAC) to curb energy use in residential buildings. Given the concerns about draught discomfort and thermal stratification associated with floor-based air-conditioning systems, the objective of this study is to evaluate the air distribution performance and to quantify the possible energy benefits. Bedroom was chosen as a sensitive case for detailed air distribution performance evaluation. Experimental study, CFD simulations and energy simulations were conducted in achieving the specific objectives. CAC and FAC were installed in a bedroom-like environmental chamber for experimental study at different indoor and outdoor conditions. The air velocities and temperatures at various positions and levels inside the chamber were measured to determine the air distribution performance indices (ADPI) and airflow draft risk (DR). The cooling output, power consumption and coefficient of performance (COP) of the two units were measured and calculated for comparison. The experimental results show that ADPI of CAC and FAC are 92.3% and 84.6%, respectively. COP of FAC is 8.11% higher than CAC, and the corresponding DR are comparable. The experimental results were used to validate the CFD simulations as well as providing actual performance data for predicting the energy use of applying CAC and FAC in a case-study building. CFD simulations and draught assessment confirmed that there is no potential draught discomfort and thermal stratification associated with the use of FAC. Energy simulations predicted that the associated energy saving is 6.9%. Wider use of FAC in residential buildings is therefore recommended.

10/00718 Long-term thermal performance of a two-phase thermosyphon solar water heater

Chen, B.-R. *et al. Solar Energy*, 2009, 83, (7), 1048–1055.

This article investigates experimentally the long-term thermal performance of a two-phase thermosyphon solar water heater and compares the results with the conventional systems. Experimental investigations are conducted to obtain the system thermal efficiencies from the hourly, daily and long-term performance tests. Different heat transfer mechanisms, including natural convection, geyser boiling, nucleate boiling and film-wise condensation, are observed in the two-phase thermosyphon solar water heater while solar radiation varies. The thermal performance of the proposed system is compared with that of four conventional solar water heaters. Results show that the proposed system achieves system characteristic efficiency 18% higher than that of the conventional systems by reducing heat loss for the two-phase thermosyphon solar water heater.

10/00719 Market diffusion, technological learning, and cost-benefit dynamics of condensing gas boilers in the Netherlands

Weiss, M. *et al. Energy Policy*, 2009, 37, (8), 2962–2976.

High costs often prevent the market diffusion of novel and efficient energy technologies. Monitoring cost and price decline for these technologies is thus important in order to establish effective energy policy. The authors present experience curves and cost-benefit analyses for condensing gas boilers produced and sold in the Netherlands between 1981 and 2006. For the most dominant boiler type on the Dutch market, i.e. condensing gas combi boilers,learning rates of 14±1% were identified for the average price and 16±8% for the additional price relative to non-condensing devices. Economies of scale, competitive sourcing of boiler components, and improvements in boiler assembly are among the main drivers behind the observed price decline. The net present value of condensing gas combi boilers shows an overall increasing trend. Purchasing in 2006 a gas boiler of this type instead of a non-condensing device generates a net present value of €970 and realizes CO_2 (carbon dioxide) emission savings at negative costs of −€120 per tonne CO_2. Two-thirds of the improvements in the cost-benefit performance of condensing gas combi boilers were attributed to technological learning and one-third to a combination of external effects and governmental policies.

10/00720 Market influence on the low carbon energy refurbishment of existing multi-residential buildings

Atkinson, J. G. B. *et al. Energy Policy*, 2009, 37, (7), 2582–2593.

This paper explores the relationship between the energy market; the political and regulatory context; and energy design decisions for existing multi-residential buildings, to determine what form the energy market landscape would take if tailored to encourage low carbon solutions. The links between market dynamics, government strategies, and building designs are mapped to understand the steps that achieve carbon reduction from building operation. This is achieved using a model that takes financial and energy components with market and design variables to provide net present cost and annual carbon outputs. The financial component applies discounted cash flow analysis over the building lifespan, with discount rates reflecting contractual characteristics; the carbon component uses standard assessment procedure (SAP) 2005. A scenario approach is adopted to test alternative strategies selected to encourage low carbon solutions in two residential and two office designs. The results show that the forward assumption of energy price escalation is the most influential factor on energy investment, together with the expected differentiation between the escalation of gas and electricity prices. Using this, and other influencing factors, the research reveals trends and strategies that will achieve mainstream application of energy efficiency and microgeneration technologies, and reduce carbon emissions in the existing multi-residential sector.

10/00721 Neural networks analysis of thermal characteristics on plate-fin heat exchangers with limited experimental data

Peng, H. and Ling, X. *Applied Thermal Engineering*, 2009, 29, (11–12), 2251–2256.

In this paper, an application of artificial neural networks (ANNs) was presented to predict the pressure drop and heat transfer characteristics in the plate-fin heat exchangers (PFHEs). First, the thermal performances of five different PFHEs were evaluated experimentally. The Colburn factor j and friction factor f to different type fins were obtained under various experimental conditions. Then, a feed-forward neural network based on back propagation algorithm was developed to model the thermal performance of the PFHEs. The ANNs was trained using the experimental data to predict j and f factors in PFHEs. Different network configurations were also examined for searching a better network for prediction. The predicted values were found to be in good agreement with the actual values from the experiments with mean squared errors less than 1.5% for j factor and 1% for f factor, respectively. This demonstrated that the neural network presented can help the engineers and manufacturers predict the thermal characteristics of new type fins in PFHEs under various operating conditions.

10/00722 Numerical study on the heat storing capacity of concrete walls with air cavities

Zhang, Z. L. and Wachenfeldt, B. J. *Energy and Buildings*, 2009, 41, (7), 769–773.

Finite element analyses using COMSOL have been carried out to study the heat transfer behaviour and storing capacity of concrete walls with air cavities, and to explore the possibility of using one-layer and two-layer one-dimensional models with equivalent thermal conductivity and mass density to represent the effect of concrete walls with air cavities in a building energy simulation. Three typical wall geometries were chosen and both stationary and transient analyses have been carried out. The stationary analyses were performed first to find the equivalent thermal conductivity which was further used in the transient analyses to fit the equivalent mass density. Because of the presence of air cavities the equivalent thermal conductivities are always smaller than the bulk thermal conductivity. However, for the one-layer model an exaggerated equivalent mass density as high as two times the bulk density should be used in order to simulate the heat storing capacity of the concrete walls with air cavities. The values of the fitted equivalent mass density are strongly dependent on the wall thickness.

10/00723 On-road performance analysis of R134a/R600a/R290 refrigerant mixture in an automobile air-conditioning system with mineral oil as lubricant

Ravikumar, T. S. and Lal, D. M. *Energy Conversion and Management*, 2009, 50, (8), 1891–1901.

R134a has been accepted as the single major refrigerant in the automobile industry and it has been used worldwide. But, the problem associated with it is the use of the PAG oil as the lubricant. Unlike the conventional mineral oil, the synthetic PAG oil used with R134a is highly hygroscopic in nature. The PAG lubricants come with different additives unique for different compressors. This leads to serious service issues. Therefore, a refrigerant, which will be readily available to replace R12, and also compatible with mineral oil, is needed. In the present study the readily available R134a is used in place of R12. However, to avoid PAG oil and to use the conventional mineral oil as lubricant, R134a is mixed with the commercially available hydrocarbon blend, (45.2% R290 and 56.8% R600a) in the proportion of 91% and 9%, respectively by mass. The quantity of hydrocarbons used is well below the lower flammable limit. This new mixture R134a/R600a/R290 is tested in the air-conditioning system of a passenger car 'on road' in the true running conditions and compared with the results that has been obtained with R12. The cool down performance under varying speed and varying ambient conditions, system performance under severe accelerating conditions and bumper-to-bumper traffic conditions is studied. The test results show that the new blend can be a promising substitute for the existing R12 systems and it can eliminate the use of hygroscopic PAG oil.

10/00724 Phase change characteristic study of spherical PCMs in solar energy storage

Veerappan, M. *et al. Solar Energy*, 2009, 83, (8), 1245–1252.

This paper investigates the phase change behaviour of 65 mol% capric acid and 35 mol% lauric acid, calcium chloride hexahydrate, *n*-octadecane, *n*-hexadecane, and *n*-eicosane inside spherical enclosures to identify a suitable heat storage material. Analytical models are developed for solidification and melting of sphere with conduction, natural convection, and heat generation. Both the models are validated with previous experimental studies. Good agreement was found between the analytical predictions and experimental study and the deviations were lesser than 20%. Heat flux release at the wall, cumulative energy release to the external fluid, are revealed for the best PCM. The influence of the size of encapsulation, initial temperature of the PCM, the external fluid temperature on solidified and molten mass fraction, and the total phase change time are also investigated.

10/00725 Prediction of an effective cooling output of the fin-and-tube heat exchanger under frosting conditions

Lenic, K. *et al. Applied Thermal Engineering*, 2009, 29, (11–12), 2534–2543.

In the paper, an analysis of heat and mass transfer during frost formation on a fin-and-tube heat exchanger has been presented. For calculation of an exchanged heat flux, a transient two-dimensional mathematical model of frost formation has been developed and numerically solved. The mathematical model and numerical procedure have been experimentally validated. For determination of an effectively exchanged heat flux inside the heat exchanger, the influence of the augmented heat transfer resistance and impact of the defrosting process have been taken into account. A detailed calculation of the frost growth rate has been a base for determination of heat transfer resistance of the frost layer. The influence of frost formation on the overall heat transfer coefficient has also been analysed. The effective exchanged heat flux has been calculated for different operating conditions, durations of cooling cycle as well as defrosting heat fluxes. Results have shown that the effectively exchanged heat flux significantly depends on operating conditions, such as air humidity and temperature, as well as the cooling cycle duration.

10/00726 Preparation and application effects of a novel form-stable phase change material as the thermal storage layer of an electric floor heating system

Li, J. *et al. Energy and Buildings*, 2009, 41, (8), 871–880.

A novel form-stable phase change material (FSPCM) was prepared, which comprises micro-encapsulated paraffin (MEP) as the latent heat storage medium and high density polyethylene/wood flour composite as the matrix. It has the following merits: proper phase transition temperature, large apparent specific heat in phase change temperature region, suitable thermal conductivity, good shape retention and dimensional stability. Therefore, it is suitable for the applications in energy efficient buildings without encapsulation. Simulation studies were performed to investigate the temperature-regulating and cost-reduction effects of the FSPCM as the thermal storage layer (TSL) material of an electric floor heating system (EFHS). The results show that it is promising to use the FSPCM plate as the TSL to achieve better temperature-regulating and cost-reduction effects, and the application effects depend on the heating mode of the EFHS and the thickness of FSPCM plates. The cost-benefit analysis indicates also that the prepared FSPCM has the potential to serve as the TSL in an electric floor heating system.

10/00727 Revamp study of crude distillation unit heat exchanger network: energy integration potential of delayed coking unit free hot streams

Bulasara, V. K. *et al. Applied Thermal Engineering*, 2009, 29, (11–12), 2271–2279.

This work addresses the revamp study of the crude distillation unit (CDU) heat exchanger network (HEN) of a typical refinery with and without the consideration of the free hot streams available in the delayed coking unit (DCU). Based on pinch design method, two sub-cases of revamp study have been considered namely (a) installation of new heat exchangers for the entire network and (b) reutilization of existing heat exchangers. Based on the study, it has been evaluated that the revamp design of existing CDU HEN without considering the DCU free hot streams allows the enhancement of heat integration by 4.73% with respect to that available for the base case. On the other hand, the heat integration potential of DCU free hot streams is evaluated to enhance energy integration by 15.66% (with respect to the base case) with a simultaneous reduction of furnace duty by 37.1% and cooling water duties by 89.8%. Of various cases considered, the most attractive option corresponds to the partial revamp of CDU HEN along with DCU free hot streams that involve the reutilization of existing heat exchangers. The profitability analysis of this option concludes that the revamp design needs an additional investment of M$2.68 to enhance annual profit by M$1.58 with a payback period of 1.9 years. Thereby, the heat integration potential of DCU free hot streams is inferred to be significant and marks an important choice amongst different key revamp parameters associated to heat exchanger networks.

10/00728 Simulation and analysis of a novel liquid desiccant air-conditioning system

Tu, M. *et al. Applied Thermal Engineering*, 2009, 29, (11–12), 2417–2425.

In this work a novel energy efficient air-conditioning system utilizing lithium chloride (LiCl) solution as liquid desiccant has been proposed and simulated. The simulation of this system is mainly formulated with two packed columns, one for regenerating the weak desiccant and the other for the dehumidification of ambient air. The air is first dehumidified in the dehumidifier and then sensibly cooled in the indirect and direct evaporative coolers. First and second laws of thermodynamics have been used to analyse the effect of five key variables on the performance of the system. High efficiency could be achieved if proper values of these variables are selected.

10/00729 Single-phase experimental analysis of heat transfer in helically finned heat exchanger

Martinez, E. *et al. Applied Thermal Engineering*, 2009, 29, (11–12), 2205–2210.

A methodology for designing helically serrated finned tube heat exchanger based on the logarithmic mean temperature difference (LMTD) method is validated with experimental tests. The method uses semi-empirical correlations for calculating convective coefficients both inside and outside staggered tube bundles. Equipment was designed, built, and installed in a paper factory in order to validate the methodology. Comparisons between predictions and experimental data show a precision of approximately 96% in heat transfer and approximately 90% in pressure drop for Reynolds numbers upper to 10,000.

10/00730 Steady-state analysis of CO_2 based natural circulation loops with end heat exchangers

Kumar, K. K. and Gopal, M. R. *Applied Thermal Engineering*, 2009, 29, (10), 1893–1903.

This study presents the results obtained from the steady-state analysis of single-phase rectangular natural circulation loops with parallel flow, tube-in-tube type heat exchangers. Due to certain favourable properties, CO_2 is chosen as the secondary fluid in the loop. Water is used as the external fluid in both hot and cold heat exchangers. Using a simple analytical expression, it is first shown that use of CO_2 in place of water can result in a compact loop. The results obtained are found to match with the results obtained using the analytical expressions, which are generally used as first approximations for the steady-state behaviour of natural circulation loops. However, unlike the classic expressions, the method suggested here is general as it considers the heat exchanger configuration, non-symmetric geometry and variable properties, so that it can be used for optimal system design. The results obtained on a rectangular loop show that for a given input data there exist optimum values for heat exchanger length and tube diameters. It is also seen that the external fluid flow rate does not influence the loop performance significantly beyond a certain value. However, the temperatures of external fluids affect the loop performance strongly.

10/00731 Study of ventilation cooling technology for telecommunication base stations in Guangzhou

Chen, Y. *et al. Energy and Buildings*, 2009, 41, (7), 738–744.

Telecommunication base stations (TBSs) in Guangzhou, China are used in large numbers, and have high heat density, a long cooling season and high energy consumption. To make full use of natural outdoor cooling resources, a new ventilation cooling technology (VCT) is proposed. As the heat from the telecommunication equipment can be dissipated directly by outdoor cold air, the runtime of the air conditioners can be shortened by VCT, resulting in notable energy savings. Based on field investigation of a typical TBS, VCT was studied systematically. The results show that the application of VCT to the TBSs in Guangzhou is feasible, the energy saving for VCT is about 49% and the payoff period is less than two years. Obvious economic and social benefits will be achieved, provided that VCT can be broadly applied. Also, computational fluid dynamics simulation results indicate that optimization of airflow organization has a strong influence on heat dissipation efficiency for VCT.

10/00732 Study on the design procedure for a multi-cool/heat tube system

Yoon, G. *et al. Solar Energy*, 2009, 83, (8), 1415–1424.

This study considers the design of an earth-to-air heat exchanger system consisting of multiple pipes with a close arrangement. A numerical model for this multi-cool/heat tube system was developed and verified by field measurements. By taking into account the thermal interference between tubes, the heat transfer performance was evaluated under various design conditions such as number of tubes, arrangement interval, air velocity and length, and soil properties. Based on these results, an estimation method for the heat transfer rate for the multi-cool/heat tube system is proposed.

10/00733 Synthetical optimization of hydraulic radius and acoustic field for thermoacoustic cooler

Kang, H. *et al. Energy Conversion and Management*, 2009, 50, (8), 2098–2105.

It is well known that the acoustic field and the hydraulic radius of the regenerator play key roles in thermoacoustic processes. The optimization of hydraulic radius strongly depends on the acoustic field in the regenerator. This paper investigates the synthetical optimization of hydraulic radius and acoustic field which is characterized by the ratio of the traveling wave component to the standing wave component. The authors also discuss the heat flux, cooling power, temperature gradient and coefficient of performance of thermoacoustic cooler with different combinations of hydraulic radiuses and acoustic fields. The calculation results show that, in the cooler's regenerator, due to the acoustic wave, the heat is transferred towards the pressure antinodes in the pure standing wave, while the heat is transferred in the opposite direction of the wave propagation in the pure traveling wave. The better working condition for the regenerator appears in the traveling wave phase region of the like-standing wave, where the directions of the heat transfer by traveling wave component and standing wave component are the same. Otherwise, the small hydraulic radius is not a good choice for acoustic field with excessively high ratio of traveling wave, and the small hydraulic radius is only needed by the travelling wave phase region of like-standing wave.

10/00734 The effect of false ceiling on the cooling capacity of passive chilled beams

Fredriksson, J. and Sandberg, M. *Building and Environment*, 2009, 44, (7), 1426–1430.

Passive chilled beams are often used to provide cooling or additional cooling when the ventilation system cannot cope with the whole cooling load. The advantage of passive cooling is that it is a silent cooling. Often the chilled beams are installed above a false ceiling and thereby the room is subdivided into two compartments. From the chilled beam a plume is generated. Make-up air (return air) needs to flow into the upper compartment to substitute the airflow generated by the chilled beam. Therefore openings for this purpose are installed in the false ceiling. Small openings constitute a resistance to the flow and the locations of the openings affect the flow pattern. The overall performance was studied in a mock-up of a real office by changing both the size and position of the openings for the make-up air. A uniform heating source was arranged by covering the floor with a heating foil. The best location and size of the openings were explored by both recording the heat absorbed by the beam and the temperature in the room. Minimum temperature attained in the room is the signature of the most efficient cooling. To achieve efficient cooling with a uniform floor-based heating source, two conditions must be fulfilled: (a) the return opening area must be at least equal to the horizontal area of the chilled beam; (b) the return air openings must be located at the perimeter of the room. In general conditions (a) and (b) can be expected to be applicable irrespective of type of heat, but for point sources the best cooling can be achieved by placing the return air opening above the heat source.

10/00735 The effects of night ventilation technique on indoor thermal environment for residential buildings in hot-humid climate of Malaysia

Kubota, T. *et al. Energy and Buildings*, 2009, 41, (8), 829–839.

This study investigates the effectiveness of night ventilation technique for residential buildings in hot-humid climate of Malaysia. This paper firstly presents the results of a survey on usage patterns of windows and air-conditioners in typical Malaysian residential areas. Secondly, the effects of different natural ventilation strategies on indoor thermal environment for Malaysian terraced houses are evaluated based on the results of a full-scale field experiment. The results show that the majority of occupants tend to apply not night ventilation but daytime ventilation in Malaysian residential areas. It can be seen from the field experiment that night ventilation would provide better thermal comfort for occupants in Malaysian terraced houses compared with the other ventilation strategies in terms of operative temperature. However, when the evaporative heat loss of occupants is taken into account by using SET*, the night ventilation would not be the superior technique to the others in providing daytime thermal comfort mainly due to the high humidity conditions. Therefore, the indoor humidity control during the daytime such as by dehumidification would be needed when the night ventilation technique is applied to Malaysian terraced houses. Otherwise, full-day ventilation would be a better option compared with night ventilation.

10/00736 Theoretical and experimental investigations of a liquid desiccant filmed cellulose fibre heat and mass exchanger

Liu, S. *et al. International Journal of Energy Research*, 2009, 33, (12), 1076–1088.

This paper presented theoretical and experimental investigations of a liquid desiccant filmed cellulose fibre heat and mass exchanger, a new type of exchanger with the potential to be an alternative to a conventional exchanger. Owing to the complexity of the desiccant assisted heat and mass transfer and difficulty in determining its associated parameters, work started from the simulation of a clear fibre exchanger by developing a dedicated numerical model, and its validation by using the data from the manufacturer of the exchanger. Further to this, laboratory testing was carried out with the same exchanger, but filmed with a liquid desiccant fluid, i.e. LiCl. Comparison between the data of the clear and desiccant filmed exchangers suggested the use of correction factors for heat and mass transfer resistances with desiccant operation. A revised model for the desiccant filmed exchanger was then established taking into account the correction factors. By using the updated model, influence of geometrical sizes and operating conditions of the liquid desiccant filmed exchanger on the exchanger efficiency were studied and the optimal values of these were obtained. The results indicated that the exchanger efficiencies (heat, mass and enthalpy) are largely dependent upon the exchanger channel length, air flow rate and less related to the exchanger channel height, intake air temperature and intake-to-outgoing air moisture content difference. It was also suggested that the air speed across the channels should be in the range 0.5–1.5 m s^{-1}. The height of air channel (passage) should be set at 6.5 mm or below and its length should be 1.0 m or more. A simulation was carried out under UK typical summer operation conditions, i.e. the intake air streams at 30°C db and 70% rh and outgoing air streams at 24°C db and 50% rh, and the results indicated that the exchanger with the above recommended geometrical sizes can achieve an energy efficiency of 87%, which is 30% higher than for non-desiccant filmed operation.

10/00737 Thermodynamic optimization of a stratified thermal storage device

Jack, M. W. and Wrobel, J. *Applied Thermal Engineering*, 2009, 29, (11–12), 2344–2349.

Thermodynamic optimization combines exergy analysis with dynamical modelling to determine optimal design parameters. This study applies exergy analysis to an analytically solvable model of a single-medium stratified thermal storage device. A simple one-dimensional model was considered that included conductive losses to the environment. Competition between mixing and conductive losses gives rise to a thermodynamically optimum charging time for the system. The model can treat the full range of stratification from the fully mixed limit to perfect stratification and the effect of stratification can be determined on the thermodynamic optimum. The authors show that stratification increases the overall efficiency and shortens the thermodynamically optimum charging time.

11 ENGINES

Power generation and propulsion, electrical vehicles

10/00738 A parametric study on the performance parameters of a twin-spark SI engine

Altin, I. and Bilgin, A. *Energy Conversion and Management*, 2009, 50, (8), 1902–1907.

A spark-ignition (SI) engine cycle model was used to study the effects of spark plug location on a twin-spark plug SI engine performance. A two-zone quasi-dimensional combustion model with a spherically developing flame propagation assumption was applied. Constructed simulation can be used for either single- or twin-spark plug configuration. For the twin-spark arrangement, spark plugs were considered to be located diametrically opposite to each other on cylinder head axisymmetrically. According to dimensionless distance from the cylinder centre to spark plug location on cylinder head, $r_{sd} = r_s/R$, five locations ($r_{sd} = 0$, 0.25, 0.50, 0.75, and 1.0) were considered. Inevitably $r_{sd} = 0$ corresponds to the single-spark arrangement that the plug is located at the centre. To comparison, single-spark plug configurations were also considered for other selected spark plug locations. From the result of the study it was found that centrally located single-spark plug arrangement gives the best engine performance and fuel economy, while for the all the other spark-plug locations away from the centre twin-spark arrangement favourable to the single-spark plug configuration.

10/00739 A soot formation embedded reduced reaction mechanism for diesel surrogate fuel

Chen, W. *et al. Fuel*, 2009, 88, (10), 1927–1936.

A reduced diesel surrogate fuel chemical reaction mechanism of *n*-heptane/toluene was developed, the reduced mechanism (referred as the 'THU mechanism') includes 60 species and 145 reactions, and it contains soot formation reactions. The THU mechanism was developed from the existing *n*-heptane/toluene mechanism (70 species and 313 reactions) of Chalmers University of Technology (referred as the 'CTH mechanism'). SENKIN and XSENKPLOT were used to analyse the important reactions and species during *n*-heptane, toluene oxidation and soot formation processes to formulate the reduced mechanism. Ignition delays of *n*-heptane and toluene predicted by the THU mechanism match well with the CTH mechanism and shock-tube test data under different conditions. The THU and CTH mechanisms also show similar soot concentration prediction. The global reaction of diesel fuel decomposed into *n*-heptane and toluene with mole fraction 7:3 was built to accelerate the decomposition and advance ignition timing. Kinetic constants of soot oxidation reactions were adjusted to reduce the soot oxidation rate. The THU mechanism was coupled with the KIVA-3V Release 2 code to model diesel combustion processes in the constant-volume combustion vessel and optical diesel engine of Sandia. The predicted ignition delay, in-cylinder pressure and heat release rate match the experimental results well. The predicted spatial and temporal soot concentration distributions have similar trend with the experiments.

10/00740 A speed estimation unit for induction motors based on adaptive linear combiner

Marei, M. I. *et al. Energy Conversion and Management*, 2009, 50, (7), 1664–1670.

This paper presents a new induction motor speed estimation technique, which can estimate the rotor resistance as well, from the measured voltage and current signals. Moreover, the paper utilizes a novel adaptive linear combiner (ADALINE) structure for speed and rotor resistance estimations. This structure can deal with the multi-output systems and it is called MO-ADALINE. The model of the induction motor is arranged in a linear form, in the stationary reference frame, to cope with the proposed speed estimator. There are many advantages of the proposed unit such as wide speed range capability, immunity against harmonics of measured waveforms, and precise estimation of the speed and the rotor resistance at different dynamic changes. Different types of induction motor drive systems are used to evaluate the dynamic performance and to examine the accuracy of the proposed unit for speed and rotor resistance estimation.

10/00741 Air–fuel mixing and combustion in a small-bore direct injection optically accessible diesel engine using a retarded single injection strategy

Fang, T. *et al. Fuel*, 2009, 88, (11), 2074–2082.

In this paper, the air–fuel mixing and combustion in a small-bore direct injection optical diesel engine were studied for a retarded single injection strategy. The effects of injection pressure and timing were analysed based on in-cylinder heat release analysis, liquid fuel and vapour fuel imaging by laser-induced exciplex fluorescence technique, and combustion process visualization. Nitrogen oxide emissions were measured in the exhaust pipe. Results show that increasing injection pressure benefits soot reduction while increases nitrogen oxide emissions. Retarding injection timing leads to simultaneous reduction of soot and nitrogen oxide emissions with premixed homogeneous charge compression ignition-like combustion modes. The vapour distribution in the cylinder is relatively homogeneous, which confirms the observation of premixed combustion in the current studies. The postulated path of these combustion modes were analysed and discussed on the equivalence ratio-temperature map.

10/00742 Biodiesel combustion in an optical HSDI diesel engine under low load premixed combustion conditions

Fang, T. *et al. Fuel*, 2009, 88, (11), 2154–2162.

An optically accessible single-cylinder high-speed direct-injection diesel engine was used to investigate the spray and combustion processes for biodiesel blends under different injection strategies. The experimental results indicated that the heat release rate was dominated by a premixed combustion pattern and the heat release rate peak became smaller with injection timing retardation. The ignition and heat release rate peak occurred later with increasing biodiesel content. Fuel impingement on the wall was observed for all test conditions. The liquid penetration became longer and the fuel impingement was stronger with the increase of biodiesel content. Early and late injection timings result in lower flame luminosity due to improved mixing with longer ignition delay. For all the injection timings, lower soot luminosity was seen for biodiesel blends than pure diesel fuel. Furthermore, nitrogen oxide emissions were dramatically reduced for premixed combustion mode with retarded post-TDC injection strategies.

10/00743 Comparison of performance characteristics of agricultural tractor diesel engine operating on home and industrially produced biodiesel

Gravalos, I. *et al. International Journal of Energy Research*, 2009, 33, (12), 1048–1058.

Owing to unstable diesel fuel prices in the world market, many farmers have been looking for alternative fuels. Vegetable oils are one of the alternatives, which can be used as fuel in diesel engines either in the form of straight vegetable oil or in the form of biodiesel. This study aims to present experimental data by utilization of home and industrial biodiesel as fuel in an agricultural tractor diesel engine. The home biodiesel production was made from different vegetable oils (crude rapeseed, edible sunflower and waste oil) with the process of one-stage-based catalyzed transesterification. A commercially available agricultural tractor ZETOR 7745 was employed. Measurements were taken on the power take-off shaft by electrical dynamometer FROMENT XT200. According to the results, agricultural tractor diesel engine operating on home biodiesel fuels had better performance characteristics related to industrially produced biodiesel and similar to conventional diesel fuel.

10/00744 Determination of ecological efficiency in internal combustion engines: the use of biodiesel

Coronado, C. R. *et al. Applied Thermal Engineering*, 2009, 29, (10), 1187–1892.

This paper evaluates and quantifies the environmental impact from the use of some renewable fuels and fossils fuels in internal combustion engines. The following fuels are evaluated: gasoline blended with anhydrous ethyl alcohol (anhydrous ethanol), conventional diesel fuel, biodiesel in pure form and blended with diesel fuel, and natural gas. For the case of biodiesel, its complete life cycle and the closed carbon cycle (photosynthesis) were considered. The ecological efficiency concept depends on the environmental impact caused by CO_2, SO_2, NO_x and particulate material (PM) emissions. The exhaust gases from internal combustion engines, in the case of the gasoline (blended with alcohol), biodiesel and biodiesel blended with conventional diesel, are the less polluting; on the other hand, the most polluting are those related to conventional diesel. They can cause serious problems to the environment because of their dangerous components for the human, animal and vegetable life. The resultant pollution of each one of the mentioned fuels are analysed, considering separately CO_2, SO_2, NO_x and particulate material (PM) emissions. As conclusion, it is possible to calculate an environmental factor that represents, qualitatively and quantitative, the emissions in internal combustion engines that are mostly used in urban transport. Biodiesel in pure form (B100) and blended with conventional diesel as fuel for engines pollute less than conventional diesel fuel. The ecological efficiency for pure biodiesel (B100) is 86.75%; for biodiesel blended with conventional diesel fuel (B20, 20% biodiesel and 80% diesel), it is 78.79%. Finally, the ecological efficiency for conventional diesel, when used in engines, is 77.34%; for gasoline, it is 82.52%, and for natural gas, it is 91.95%. All these figures considered a thermal efficiency of 30% for the internal combustion engine.

10/00745 Effect of advancing the closing angle of the intake valves on diffusion-controlled combustion in a HD diesel engine

Benajes, J. *et al. Applied Thermal Engineering*, 2009, 29, (10), 1947–1954.

An experimental investigation has been performed on the modification of in-cylinder gas thermodynamic conditions by advancing the intake valve closing angle in a HD diesel engine. The consequences on the diffusion-controlled combustion process have been analysed in detail, including the evolution of exhaust emissions and engine efficiency. This research has been carried out at full load (100%) and low engine speed (1200 rpm) with the aim of generating a long and stable diffusion-controlled combustion process. The intake oxygen mass concentration was kept at 17.4% to obtain low NO_x levels in all cases. The required flexibility on intake valve motion has been attained by means of an electro-hydraulic variable valve actuation system. The results obtained from advancing the intake valve closing angle (IVC) have shown an important reduction on in-cylinder gas pressure and density, whereas the gas temperature showed less sensitivity. Consequently, the diffusion-controlled combustion process is slowed down mainly due to the lower in-cylinder gas density and oxygen availability. Important effects of advancing IVC have also been observed on pollutant emissions and engine efficiency. Where NO_x production decreases, soot emissions increase. Finally, the results of pollutant emissions and engine efficiency have been compared with those obtained retarding the start of injection.

10/00746 Effects of ethyl *tert*-butyl ether addition to diesel fuel on characteristics of combustion and exhaust emissions of diesel engines

Li, T. *et al. Fuel*, 2009, 88, (10), 2017–2024.

The effects of ethyl *tert*-butyl ether (ETBE) addition to diesel fuel on the characteristics of combustion and exhaust emissions of a common rail direct injection diesel engine with high rates of cooled exhaust gas recirculation (EGR) were investigated. Test fuels were prepared by blending 0, 10, 20, 30 and 40 vol% ETBE to a commercial diesel fuel. Increasing ETBE fraction in the fuel helps to suppress the smoke emission increasing with EGR, but a too high fraction of ETBE leads to misfiring at higher EGR rates. While the combustion noise and NO_x emissions increase with increases in ETBE fraction at relatively low EGR rates, they can be suppressed to low levels by increasing EGR. Though there are no significant increases in THC and CO emissions due to ETBE addition to diesel fuel in a wide range of EGR rates, the ETBE blended fuel results in higher aldehyde emissions than the pure diesel fuel at relatively low EGR rates. With the 30% ETBE blended fuel, the operating load range of smokeless, ultra-low NO_x (<0.5 g/kWi h), and efficient diesel combustion with high rates of cooled EGR is extended to higher loads than with the pure diesel fuel.

10/00747 Effects of nozzle geometry on direct injection diesel engine combustion process

Payri, R. *et al. Applied Thermal Engineering*, 2009, 29, (10), 2051–2060.

The aim of the current article is to link nozzle geometry, and its influence on spray characteristics, with combustion characteristics in the chamber. For this purpose, three six-hole sac nozzles, with different orifices degree of conicity, have been used. These nozzles had been geometrically and hydraulically characterized in a previous publication, where also a study of liquid phase penetration and stabilized liquid length in real engine conditions has been done. In the present work, CH and OH chemiluminescence techniques are used to thoroughly examine combustion process. CH-radicals are directly related to pre-reactions, which take place once the fuel has mixed with air and it has evaporated. On the other hand, OH-radicals data provide information about the location of the flame front once the combustion has begun. The analysis of all the results allows linking nozzle geometry, spray behaviour and combustion development. In particular, CH-radicals have shown to appear together with vapour spray, both temporally and in their location, being directly related to nozzle characteristics. Additionally, analysis of ignition delay is done form OH measurements, including some correlations in terms of chamber properties, injection pressure and nozzle diameter.

10/00748 Engine performance and emission characteristics of marine fish-oil biodiesel produced from the discarded parts of marine fish

Lin, C.-Y. and Li, R.-J. *Fuel Processing Technology*, 2009, 90, (7–8), 883–888.

Biodiesel is recognized as a clean alternative fuel or as a fuel additive to reduce pollutant emissions from combustion equipment. Because cultivated land is too limited to grow seed-oil plants sufficient to produce both food and biodiesel, non-land-based oleaginous materials have been considered important sources for the production of the latter. In this study, the discarded parts of mixed marine fish species were used as the raw material to produce biodiesel. Marine fish oil was extracted from the discarded parts of mixed marine fish and refined through a series of pretreatment processes. The refined marine fish oil was then transesterified with methyl alcohol to produce biodiesel, which was used thereafter as engine fuel to investigate its engine performance and emission characteristics. The experimental results show that, compared with commercial biodiesel from waste cooking oil, marine fish-oil biodiesel has a larger gross heating value, elemental carbon and hydrogen content, cetane index, exhaust gas temperature, brake fuel conversion efficiency, NO_x and O_2 emissions, and black smoke opacity and a lower elemental oxygen content, fuel consumption rate, brake-specific fuel consumption rate, equivalence ratio, and CO emission. Compared with ASTM No. 2D diesel, both marine fish-oil and waste cooking-oil biodiesels appear to have a lower gross heating value, cetane index, exhaust gas temperature, equivalence ratio, black smoke opacity, elemental carbon content, and CO emission and a higher fuel consumption rate and elemental oxygen content.

10/00749 Fuel efficiency of vehicles on US roads: 1923–2006

Sivak, M. and Tsimhoni, O. *Energy Policy*, 2009, 37, (8), 3168–3170.

This article documents and analyses the changes in fuel efficiency of vehicles on US roads between 1923 and 2006. Information about distances driven and fuel consumed was used to calculate the on-the-road fuel efficiency of the overall fleet and of different classes of vehicles. The overall fleet fuel efficiency decreased from 14 mpg in 1923 to 11.9 mpg in 1973. Starting in 1974, efficiency increased rapidly to 16.9 mpg in 1991. Thereafter, improvements have been small, with efficiency reaching 17.2 mpg in 2006. The information for 2006 was used to calculate the fuel-efficiency improvements in different classes of vehicles that would be needed to achieve a given percentage reduction in the total amount of fuel consumed by all vehicles.

10/00750 Influence of EGR unequal distribution from cylinder to cylinder on NO_x–PM trade-off of a HSDI automotive diesel engine

Maiboom, A. *et al. Applied Thermal Engineering*, 2009, 29, (10), 2043–2050.

The influence of cylinder-to-cylinder variation in exhaust gas recirculation (EGR) distribution on the NO_x–PM trade-off (while varying EGR rate) is studied on an automotive high-speed direct injection diesel engine. Experiments have been conducted on an engine test bench with and without air-EGR mixer and demonstrate that variations in cylinder-to-cylinder EGR distribution results in a deteriorated NO_x–PM trade-off (increased NO_x emissions level at a given PM emissions level, or increased PM emissions level at a given NO_x emissions level) compared to the well-mixed configuration with equal EGR rate for all the cylinders. A qualitative study as well an original experiment is conducted to explain this emissions increase induced by unequal distribution of EGR. When recirculating hot exhaust gases, the emissions increase is due to cylinder-to-cylinder variations in intake gas composition and temperature.

10/00751 Performance optimization of Jatropha biodiesel engine model using Taguchi approach

Ganapathy, T. *et al. Applied Energy*, 2009, 86, (11), 2476–2486.

This paper proposes a methodology for thermodynamic model analysis of jatropha biodiesel engine in combination with Taguchi's optimization approach to determine the optimum engine design and operating parameters. A thermodynamic model based on two-zone Weibe's heat release function has been employed to simulate the jatropha biodiesel engine performance. Among the important engine design and operating parameters 10 critical parameters were selected assuming interactions between the pair of parameters. Using linear graph theory and Taguchi method an L_{16} orthogonal array has been utilized to determine the engine test trials layout. In order to maximize the performance of jatropha biodiesel engine the signal-to-noise ratio related to higher-the-better quality characteristics has been used. The present methodology correctly predicted the compression ratio, Weibe's heat release constants and combustion zone duration as the critical parameters that affect the performance of the engine compared to other parameters.

10/00752 Progress and recent trends in homogeneous charge compression ignition (HCCI) engines

Yao, M. *et al. Progress in Energy and Combustion Science*, 2009, 35, (5), 398–437.

HCCI combustion has been drawing the considerable attention due to high efficiency and lower nitrogen oxide (NO_x) and particulate matter (PM) emissions. However, there are still tough challenges in the successful operation of HCCI engines, such as controlling the combustion phasing, extending the operating range, and high unburned hydrocarbon and CO emissions. Massive research throughout the world has led to great progress in the control of HCCI combustion. The first thing paid attention to is that a great deal of fundamental theoretical research has been carried out. First, numerical simulation has become a good observation and a powerful tool to investigate HCCI and to develop control strategies for HCCI because of its greater flexibility and lower cost compared with engine experiments. Five types of models applied to HCCI engine modelling are discussed in the present paper. Second, HCCI can be applied to a variety of fuel types. Combustion phasing and operation range can be controlled by the modification of fuel characteristics. Third, it has been realized that advanced control strategies of fuel/air mixture are more important than simple homogeneous charge in the process of the controlling of HCCI combustion processes. The stratification strategy has the potential to extend the HCCI operation range to higher loads, and low temperature combustion (LTC) diluted by exhaust gas recirculation (EGR) has the potential to extend the operation range to high loads; even to full loads, for diesel engines. Fourth, optical diagnostics has been applied widely to reveal in-cylinder combustion processes. In addition, the key to diesel-fuelled HCCI combustion control is mixture preparation, while EGR is the main path to achieve gasoline-fuelled HCCI combustion. Specific strategies for diesel-fuelled, gasoline-fuelled and other alternative fuelled HCCI combustion are also discussed in the present paper.

10/00753 The development of a digestion procedure for the determination of metals in gum obtained from deposits in internal combustion engines by ICP–OES

do Socorro Vale, M. *et al. Fuel*, 2009, 88, (10), 1955–1960.

The accurate determination of metals in gum (deposits found in internal combustion engines) is strongly influenced by a selection of the right sample digestion method. The difficult and heterogeneous nature of this kind of sample, and its unpredictable reaction behaviour are the major obstacles in getting correct analytical results. The studies were implemented with one sample called 'reference sample'. Two digestion procedures were tested in this work. The dry ashing procedure was followed by another dissolution procedure with HF and heating, in order to complete the dissolution of the ash in the samples. The process was performed in 36 h. The second digestion procedure was implemented in closed system (pressurized) with 2 mL of HNO_3 and 2 mL of H_2SO_4. This last one presented a reduction of 80.5% time-consuming in relation to the first one (dry ashing). Al, Ca, Cd, Cr, Cu, Fe, K, Mg, Na, Ni, Pb, Si, and Zn were determined in 14 samples of gum by ICP–OES. The wet closed system digestion procedure showed efficiency in the Cr, Cu, Fe, K, Ni, Pb, Si, and Zn determination. The correlation matrix results contribute to the characterization studies of the gum formation process, as well as the corrosion of the motor parts and fuel quality control.

10/00754 Thermodynamic modeling of direct injection methanol fueled engines

Shen, Y. *et al. Applied Thermal Engineering*, 2009, 29, (11–12), 2379–2385.

In-cylinder pressure is an important parameter that is used to investigate the combustion process in internal combustion (IC) engines. In this paper, a thermodynamic model of IC engine combustion is presented and examined. A heat release function and an empirical conversion efficiency factor are introduced to solve the model. The pressure traces obtained by solving the thermodynamic model are compared with measured pressure data for a fully instrumented laboratory IC spark ignition (SI) engine. Derived scaling parameters for time to peak pressure, peak pressure, and maximum rate of pressure rise (among others) are developed and compared with the numerical simulations. The models examined here may serve as pedagogic tools and, when suitably refined, as preliminary design tools.

10/00755 Towards a detailed soot model for internal combustion engines

Mosbach, S. *et al. Combustion and Flame*, 2009, 156, (6), 1156–1165.

This study presents a detailed model for the formation of soot in internal combustion engines describing not only bulk quantities such as soot mass, number density, volume fraction, and surface area but also the morphology and chemical composition of soot aggregates. The new model is based on the stochastic reactor model (SRM) engine code, which uses detailed chemistry and takes into account convective heat transfer and turbulent mixing, and the soot formation is accounted for by SWEEP, a population balance solver based on a Monte Carlo method. In order to couple the gas-phase to the particulate phase, a detailed chemical kinetic mechanism describing the combustion of primary reference fuels (PRFs) is extended to include small polycyclic aromatic hydrocarbons (PAHs) such as pyrene, which function as soot precursor species for particle inception in the soot model. Apart from providing averaged quantities as functions of crank angle like soot mass, volume fraction, aggregate diameter, and the number of primary particles per aggregate for example, the integrated model also gives detailed information such as aggregate and primary particle size distribution functions. In addition, specifics about aggregate structure and composition, including C/H ratio and PAH ring count distributions, and images similar to those produced with transmission electron microscopes, can be obtained. the new model is applied to simulate an *n*-heptane fuelled homogeneous charge compression ignition engine which is operated at an equivalence ratio of 1.93. In-cylinder pressure and heat release predictions show satisfactory agreement with measurements. Furthermore, simulated aggregate size distributions as well as their time evolution are found to qualitatively agree with those obtained experimentally through snatch sampling. It is also observed both in the experiment as well as in the simulation that aggregates in the trapped residual gases play a vital role in the soot formation process.

10/00756 Transient detection of eccentricity-related components in induction motors through the Hilbert–Huang Transform

Antonino-Daviu, J. *et al. Energy Conversion and Management*, 2009, 50, (7), 1810–1820.

The identification and extraction of characteristic patterns are proposed in this work for the diagnosis and evaluation of mixed eccentricities in induction electrical machines with parallel stator branches. Whereas the classical diagnosis approaches, deeply spread in the industrial environment, are based on the Fourier analysis of the steady-state current, the basis of the proposed methodology consist of analysing the current demanded by the machine during the connection process (startup transient); the objective is to extract the characteristic evolution during the transient of some harmonic components created by the fault; this evolution is caused by the dependence of these components on the slip (*s*), a quantity varying during the startup transient from 1 to almost 0. For this feature extraction, the Hilbert–Huang transform (HHT) is proposed. An analysis of the behaviour of this transform in comparison with another time-frequency approach used in other works, the discrete wavelet transform (DWT), is also presented in the paper. The results show the usefulness of the methodology for the reliable diagnosis of the mixed eccentricity fault and for the correct discrimination against other types of failures.

Hybrid engine systems

10/00757 Aerobic biodegradation of butanol and gasoline blends

Mariano, A. P. *et al. Biomass and Bioenergy*, 2009, 33, (9), 1175–1181.
This work aimed to assess the aerobic biodegradation of butanol/gasoline blends (5; 10; 15 and 20% v/v), being the latter compared to the ethanol/gasoline blend (20% v/v). Two experimental techniques were employed, namely the respirometric method and the redox indicator DCPIP test. In the former, experiments simulating the contamination of natural environments (addition of 50 mL of fuel kg^{-1} of soil from a non-contaminated site and 20 mL of fuel L^{-1} of water from a river) were carried out in biometer flasks (250 mL), used to measure the microbial CO_2 production. The DCPIP test assessed the capability of four inocula to biodegrade the blends of 20%. The addition of butanol at different concentrations enhanced the biodegradation of gasoline in soil. However, no practical gains were observed for concentrations of butanol above 10%. Ethanol showed to have a much faster biodegradation rate than butanol, particularly in water, and the following order of biodegradability was found: ethanol > butanol > gasoline. The addition of the alcohols to the gasoline resulted in positive synergic effects on the biodegradation of the fuels in soil and water matrices. Furthermore, results suggest that, in soil, butanol better enhanced the biodegradation of gasoline than ethanol.

10/00758 Analytical framework for analyzing the energy conversion efficiency of different hybrid electric vehicle topologies

Katrašnik, T. *Energy Conversion and Management*, 2009, 50, (8), 1924–1938.
Energy consumption and exhaust emissions of hybrid electric vehicles (HEVs) strongly depend on the HEV topology, power ratios of the components and applied control strategy. There are many available patterns of combining the power flows to meet load requirements making it difficult to analyse and evaluate a newly designed HEV. In order to enhance design of HEVs, the paper provides a standalone analytical framework for evaluating energy conversion phenomena of different HEV topologies. Analytical analysis is based on the energy balance equations and considers the complete energy path in the HEVs from the energy sources to the wheels and to other energy sinks. The analytical framework enables structuring large amount of data in physically meaningful energy flows and associated energy losses, and therefore provides insightful information for HEV optimization. It therefore enables identification of most suitable HEV topology and of most suitable power ratios of the components, since it reveals and quantifies the instruments that could lead to improved energy conversion efficiency of particular HEV. The analytical framework is also applicable for correcting the energy consumption of the HEV to the value corresponding to balanced energy content of the electric storage devices.

10/00759 Experimental investigation on the performance and emissions of a diesel engine fuelled with ethanol–diesel blends

Huang, J. *et al. Applied Thermal Engineering*, 2009, 29, (11–12), 2484–2490.
An experimental investigation on the application of the blends of ethanol with diesel to a diesel engine was carried out. First, the solubility of ethanol and diesel was conducted with and without the additive of normal butanol (*n*-butanol). Furthermore, experimental tests were carried out to study the performance and emissions of the engine fuelled with the blends compared with those fuelled by diesel. The test results show that it is feasible and applicable for the blends with *n*-butanol to replace pure diesel as the fuel for diesel engine; the thermal efficiencies of the engine fuelled by the blends were comparable with that fuelled by diesel, with some increase of fuel consumptions, which is due to the lower heating value of ethanol. The characteristics of the emissions were also studied. Fuelled by the blends, it is found that the smoke emissions from the engine fuelled by the blends were all lower than that fuelled by diesel; the carbon monoxide (CO) were reduced when the engine ran at and above its half loads, but were increased at low loads and low speed; the hydrocarbon (HC) emissions were all higher except for the top loads at high speed; the nitrogen oxides (NO_x) emissions were different for different speeds, loads and blends.

10/00760 Impact of battery weight and charging patterns on the economic and environmental benefits of plug-in hybrid vehicles

Shiau, C. S. N. *et al. Energy Policy*, 2009, 37, (7), 2653–2663.
Plug-in hybrid electric vehicle (PHEV) technology is receiving attention as an approach to reducing US dependency on foreign oil and greenhouse gas (GHG) emissions from the transportation sector. PHEVs require large batteries for energy storage, which affect vehicle cost, weight, and performance. The authors construct PHEV simulation models to account for the effects of additional batteries on fuel consumption, cost, and GHG emissions over a range of charging frequencies (distance travelled between charges). They find that when charged frequently, every 20 miles or less, using average US electricity, small-capacity PHEVs are less expensive and release fewer GHGs than hybrid electric vehicles (HEVs) or conventional vehicles. For moderate charging intervals of 20–100 miles, PHEVs release fewer GHGs, but HEVs have lower lifetime costs. High fuel prices, low-cost batteries, or high carbon taxes combined with low-carbon electricity generation would make small-capacity PHEVs cost competitive for a wide range of drivers. In contrast, increased battery specific energy or carbon taxes without decarbonization of the electricity grid would have limited impact. Large-capacity PHEVs sized for 40 or more miles of electric-only travel do not offer the lowest lifetime cost in any scenario, although they could minimize GHG emissions for some drivers and provide potential to shift air pollutant emissions away from population centres. The tradeoffs identified in this analysis can provide a space for vehicle manufacturers, policymakers, and the public to identify optimal decisions for PHEV design, policy and use. Given the alignment of economic, environmental, and national security objectives, policies aimed at putting PHEVs on the road will likely be most effective if they focus on adoption of small-capacity PHEVs by urban drivers who can charge frequently.

10/00761 Optimal fuzzy power control and management of fuel cell/battery hybrid vehicles

Li, C.-Y. and Liu, G.-P. *Journal of Power Sources*, 2009, 192, (2), 525–533.
Hybrid electric vehicles powered by fuel cells have been focused for alternative powertrains due to their high efficiency and low emission. The relative engine sizing and power split strategy of different power sources have great effect in influencing the fuel economy. In this paper, for a given driving cycle, the overall efficiency of a fuel cell/battery hybrid vehicle is maximized by identifying the best degree of hybridization (DOH) and a power control strategy. Fuzzy logic is used in power distribution of the hybrid vehicle, where the optimized centres and widths of membership functions are found by optimization. Simulation results show that the optimally designed and controlled hybrid vehicle can provide good fuel economy and overall system efficiency.

10/00762 Reducing the viscosity of Jojoba Methyl Ester diesel fuel and effects on diesel engine performance and roughness

Selim, M. Y. E. *Energy Conversion and Management*, 2009, 50, (7), 1781–1788.
An experimental investigation has been carried out to test two approaches to reduce the viscosity of the jojoba methyl ester diesel fuel. The first approach is the heating of the fuel to two temperatures of 50 and 70 °C as compared to the base ambient temperature and to diesel fuel too. The second approach is adding one chemical which is considered by its own as alternative and renewable fuel which is diethyl ether. The viscosity has been reduced by both methods to close to diesel values. The performance of a diesel engine using those fuels has been tested in a variable compression research engine Ricardo E6 with the engine speed constant at 1200 rpm. The measured parameters included the exhaust gas temperature, the ignition delay period, the maximum pressure rise rate, maximum pressure, and indicated mean effective pressure and maximum heat release rate. The engine performance is presented and the effects of both approaches are scrutinized.

10/00763 Studies on the comparison of performance and emission characteristics of a diesel engine using three degummed non-edible vegetable oils

Haldar, S. K. *et al. Biomass and Bioenergy*, 2009, 33, (8), 1013–1018.
This paper investigates non-edible straight vegetable oils of putranjiva, jatropha and karanja to find out the most suitable alternative diesel by a chemical processing. Degumming is an economical chemical process that is done by concentrated phosphoric acid. This process is applied to the above-mentioned non-edible oils to remove the impurities for the improvement of viscosity, cetane number and better combustion in the diesel engine up to certain blend of diesel and non-edible vegetable oils. Ten percent, 20%, 30% and 40% blends of degummed non-edible oils and diesel are used in a Ricardo variable compression engine to study and compare the performance and emission characteristics. It is observed that the non-edible oil of jatropha gives the best results related to the performance and emissions at high loads and 45° bTDC injection timing.

10/00764 Utilization of unattended methyl ester of paradise oil as fuel in diesel engine

Devan, P. K. and Mahalakshmi, N. V. *Fuel*, 2009, 88, (10), 1828–1833.

Engine tests have been carried out with the aim of obtaining the performance, emission and combustion characteristics of a diesel engine running on methyl ester of paradise oil (MEPS) and its diesel blends. From the emission analysis it was found that there was a significant reduction in smoke and hydrocarbon emissions by 33% and 22% respectively for MEPS 50 blend and 40% and 27% reductions for MEPS 100. However, there was an increase of 5% and 8% nitrogen oxide emission for MEPS 50 and MEPS 100 respectively. Brake thermal efficiencies of MEPS and its diesel blends are slightly lower than that of standard diesel. From the engine analysis, it was found that the performance of MEPS and its diesel blends were similar to that of standard diesel.

Transport battery development

10/00765 Batteries: higher energy density than gasoline?

Fischer, M. *et al. Energy Policy*, 2009, 37, (7), 2639–2641.

The energy density of batteries is two orders of magnitude below that of liquid fuels. However, this information alone cannot be used to compare batteries to liquid fuels for automobile energy storage media. Because electric motors have a higher energy conversion efficiency and lower mass than combustion engines, they can provide a higher *deliverable mechanical* energy density than internal combustion for most transportation applications.

10/00766 Batteries: lower cost than gasoline?

Werber, M. *et al. Energy Policy*, 2009, 37, (7), 2465–2468.

This study compares the lifecycle costs of an electric car to a similar gasoline-powered vehicle under different scenarios of required driving range and cost of gasoline. An electric car is cost competitive for a significant portion of the scenarios: for cars of lower range and for higher gasoline prices. Electric cars with ~150 km range are a technologically viable, cost competitive, high performance, high efficiency alternative that can presently suit the vast majority of consumers' needs.

10/00767 Evaluation of energy consumption, emissions and cost of plug-in hybrid vehicles

Silva, C. *et al. Energy Conversion and Management*, 2009, 50, (7), 1635–1643.

Plug-in hybrid vehicles (PHEVs) are gaining attention over the world due to their ability to reduce gasoline/diesel consumption by using electricity from the grid. Despite the efforts of Society of Automotive Engineers Recommended Practice SAE J1711, it has not yet been established a worldwide methodology for calculation of fuel consumption and emission factors when regarding emission standards, with distinct driving cycles. This paper intends to contribute to the creation of this broader methodology, based on SAE J1711, aiming a fair comparison among vehicle technologies, and giving insight on electric grid impact and on CO_2 life-cycle emissions. The methodology was applied to two simulated PHEVs exploring two different powertrain configurations: series and parallel; different driving cycles: CAFE, FTP75, NEDC and JC08; different driving distances (specially analysing the average commuting daily distance of 20 km) and different user behaviours regarding battery recharging. CO_2 emissions were calculated for fuel consumption, electricity generation and cradle-to-grave. Electric grid power demand was estimated. Maintenance, manufacturer and use costs were discussed.

10/00768 Graphene nanosheets for enhanced lithium storage in lithium ion batteries

Wang, G. *et al. Carbon*, 2009, 47, (8), 2049–2053.

Graphene nanosheets were synthesized in large quantities using a chemical approach. Field emission electron microscope observation revealed that loose graphene nanosheets agglomerated and crumpled naturally into shapes resembling flower-petals. High resolution transmission electron microscope analysis, Raman spectroscopy and ultraviolet–visible spectroscopy measurements confirmed the graphitic crystalline structure of the graphene nanosheets. The nanosheets exhibited an enhanced lithium storage capacity as anodes in lithium-ion cells and good cyclic performance.

10/00769 Green energy storage materials: nanostructured TiO_2 and Sn-based anodes for lithium-ion batteries

Deng, D. *et al. Energy & Environment Science*, 2009, 2, (2), 818–837.

It is expected that the market dominance of lithium-ion batteries will continue for at least another decade as there are currently no competing alternatives with the versatility of lithium-ion batteries for powering mobile and portable devices; and for buffering the fluctuating supply of intermittent energy sources such as wind and solar. While the pursuit of higher energy density and higher power density materials constitute the bulk of current interest, there is increasing interest in durable active battery materials that can be produced with minimum environmental impact. It is with these considerations that TiO_2- and Sn-based anode materials are most interesting candidates for fulfiling future green energy storage materials. This review will focus on the recent developments of nanostructured TiO_2 and Sn-based anode materials, including rutile, anatase, TiO_2 (B), and coated TiO_2, and pristine SnO_2, and SnO_2/C, Sn(M)/C composites.

10/00770 Improvement of cyclability of Si as anode for Li-ion batteries

Ding, N. *et al. Journal of Power Sources*, 2009, 192, (2), 644–651.

Silicon working as anode for Li-ion batteries has attracted much attention due to its high capacity (~4200 mAh g^{-1}). However, due to the large volume expansion during lithiation, the capacity of silicon fades very fast. In this systematic study, the authors focus on the issue to fight the capacity fading. Results show that Si with sodium carboxymethyl cellulose (Na-CMC) as a polymer binder exhibits a better cyclability than that with poly(vinylidene fluoride) (PVDF). Yet differing from the system used in PVDF, the addition of vinylene carbonate (VC) does not improve or even worsens the performance of the system using Na-CMC. In addition, the small particle size of Si, a large amount of carbon black (CB), the good choice of electrolyte/conducting salt and charge–discharge window also play important roles to enhance the cyclability of Si. It is found that electrode consisting of 40 wt.% nano-Si, 40 wt.% carbon black and 20 wt.% Na-CMC (pH 3.5) displays the best cyclability, and in the voltage range from 0 to 0.8 V, after 200 cycles, its capacity can still keep 738 mAh g^{-1} (C/2, in 1 M $LiPF_6$ ethylene carbonate/diethyl carbonate electrolyte, with VC-free), almost twice as that of graphite.

10/00771 Optimal energy management for a series–parallel hybrid electric bus

Xiong, W. *et al. Energy Conversion and Management*, 2009, 50, (7), 1730–1738.

This paper aims to present a new type of series–parallel hybrid electric bus and its energy management strategy. This hybrid bus is a post-transmission coupled system employing a novel transmission as the series–parallel configuration switcher. In this paper, the vehicle architecture, transmission scheme and numerical models are presented. The energy management system governs the mode switching between the series mode and the parallel mode as well as the instantaneous power distribution. In this work, two separated controllers using fuzzy logic called mode decision and parallel-driving energy management are employed to fulfil these two tasks. The energy management strategy and the applications of fuzzy logic are described. The strategy is validated by a forward-facing simulation program based on the software Matlab/Simulink. The results show that the energy management strategy is effective to control the engine operating in a high-efficiency region as well as to sustain the battery charge state while satisfy the drive ability. The energy consumption is theoretically reduced by 30.3% to that of the conventional bus under transit bus driving cycle.

10/00772 Optimum sizing of photovoltaic battery systems incorporating uncertainty through design space approach

Arun, P. *et al. Solar Energy*, 2009, 83, (7), 1013–1025.

Photovoltaic-battery system is an option for decentralized power generation for isolated locations receiving abundant sunshine. A methodology for the optimum sizing of photovoltaic-battery system for remote electrification incorporating the uncertainty associated with solar insolation is proposed in this paper. The methodology used is based on the design space approach involving a time series simulation of the entire system. The design space approach was originally proposed for sizing of the system with deterministic resource and demand. The chance constrained programming approach has been used here for incorporating the resource uncertainty in the system sizing and the concept of design space is extended to incorporate resource uncertainty. The set of all feasible design configurations is represented by a sizing curve. The sizing curve for a given confidence level, connects the combinations of the photovoltaic array ratings and the corresponding minimum battery capacities capable of meeting the specified load, plotted on an array rating vs battery capacity diagram. The methodology is validated using a sequential Monte Carlo simulation approach with illustrative examples. It is shown that for the case of constant coefficient of variation of solar insolation, the set of sizing curves for different confidence levels may be represented by a generalized curve. Selection of optimum system configuration for different reliability levels based on the minimum cost of energy is also presented. The effect of ambient temperature on sizing a standalone photovoltaic-battery system is also illustrated through a representative example.

12 REFRACTORIES/ CERAMICS

Properties, production, applications

10/00773 A comparative study of naturally ventilated and gas filled windows for hot climates

Ismail, K. A. R. *et al. Energy Conversion and Management*, 2009, 50, (7), 1691–1703.

The use of absorbing gases filling the gap between glass sheets appears to be an alternative solution for thermally insulated glass windows. Fluid flow in the gap between the glass sheets either forced or natural offers other options for thermally efficient windows. In this work, the thermal efficiencies of glass windows filled with an absorbing gas exposed to solar radiation in hot climate is compared with both a simple glass window and a double glass window naturally ventilated. The two-dimensional transient energy equations with radiation absorption in the internal domain are used to model the simple glass window. The cumulative wavenumber model for real gas modelling together the discrete ordinates method is used to model double glass window filled with infrared absorbing gases. The numerical simulations were realized with three mixtures of gases, a strongly absorbing gas mixture, an intermediate absorbing gas mixture and a transparent to infrared radiation mixture. To model a double glass window naturally ventilated, a two-dimensional transient laminar incompressible flow formulation is used and the buoyancy effects are accounting for by the Bussinesq approximation. Heat transfer through the windows is calculated and the total heat gain coefficient is compared for the three types of windows.

10/00774 Effect of thermal conductivity on the efficiency of single crystal silicon solar cell coated with an anti-reflective thin film

Gaitho, F. M. *et al. Solar Energy*, 2009, 83, (8), 1290–1293.

This paper presents the working of a single crystal silicon solar cell coated with a zinc oxide thin film. Single crystalline silicon is the absorber of incident solar radiation, while the zinc oxide film – an optically black film, offers optical improvement. Thermal conductivity measurements were made using the transient line heat source (TLHS) method, where the heat source is placed against the inner and outer surfaces of the solar cell to provide heating and to sense the temperature changes at the same time. In the temperature range 297–360 K, values of thermal conductivities for the silicon material, zinc oxide and the surrounding air at atmospheric pressure were found to be $0.884–1.26 \times 10^3\,\mathrm{W\,m^{-1}\,K^{-1}}$. By comparing the calculation results for the highest and lowest values of thermal conductivities, against the solar cell output, the value of collection efficiency for photo-generated carriers in the cell is seen to be varied. At moderate values of thermal conductivity – corresponding to mid temperatures, the cell output power and hence efficiency is observed to be high.

10/00775 Enhancement of direct sulfation of limestone by Na_2CO_3 addition

Chen, C. *et al. Fuel Processing Technology*, 2009, 90, (7–8), 889–894.

For an oxy-fuel circulating fluidized bed combustion system, the limestone calcination is normally prevented due to excessive CO_2 partial pressures and the limestone is subject to a direct sulfation reaction. The enhancement of the direct sulfation of limestone by Na_2CO_3 was investigated under high CO_2 partial pressure in a thermogravimetric apparatus (TGA) and scanning electron microscope (SEM) analysis method. A commercial limestone with a mean size of 18.8 μm was used. Experimental results indicate that the incorporation of Na^+ ions in solid product $CaSO_4$ lattice structures results in formation of more extrinsic point defects in the crystal lattices of $CaSO_4$ and a significantly increased solid-state diffusivity/mobility in the solid product. So the direct sulfation of Na_2CO_3-doped limestone shows higher rate and higher degree of conversion in the later stage of sulfation, in comparison with the direct sulfation of original limestone. The reaction changes from diffusional control to chemical reaction control in the presence of Na_2CO_3 because of the effect of foreign ions on accelerating the solid-state diffusion.

10/00776 Experiment and calculation of filtration processes in an external-loop airlift ceramic membrane bioreactor

Zhang, F. *et al. Chemical Engineering Science*, 2009, 64, (12), 2859–2865.

Air sparging is recognized as an effective way to increase permeate flux in membrane filtration processes. The application of air sparging with an external-loop airlift ceramic membrane bioreactor was studied at different gas flow rates, biomass concentrations and suction pressures. A 180% increase in permeate flux was obtained while filtering a 2 g/L activated sludge wastewater suspension with the airlift cross-flow operation for $U_g = 0.21$ m/s. The mechanism of flux enhancement in the case of slug flow in tubular membrane was discussed. The region near the gas slug was divided into three different zones: falling film zone, wake zone and remaining liquid slug zone. Air sparging significantly lowered cake thickness and consequently cake resistances for the wake region and the falling film region. A novel model combining hydrodynamic of gas–liquid two-phase flow and cake resistance was developed to simulate the process. The model was validated with experimental data with an error of 8.3%.

10/00777 Non-isothermal drying of fired-clay brick, an NMR study

van der Heijden, G. H. A. *et al. Chemical Engineering Science*, 2009, 64, (12), 3010–3018.

Nuclear magnetic resonance (NMR) was used to measure moisture profiles during non-isothermal drying of fired-clay brick. Drying was induced by a temperature gradient resulting from one-sided heating. A saturated fired-clay brick sample which was closed and isolated on all sides except for the front surface was heated with a halogen lamp of variable intensity. By measuring the moisture profiles in time it was possible to identify two distinct drying stages. In the first drying stage homogeneous drying is observed. When the critical moisture content is reached a drying front enters the sample. The characteristic time t_0 after which this drying front develops depends on the applied heat flux. The total amount of energy needed for evaporation of the moisture in the first drying stage is found to be independent of the heat flux from the lamp. As a result the total amount of moisture as a function of time can be scaled to one master curve using the time t_0. The data from these measurements provided an interesting view on drying processes, not only under isothermal conditions but also under influence of a thermal gradient. By using the power input as a scaling parameter it is shown that both the total mass and the drying front positions as a function of time show the same behaviour in all experiments.

10/00778 Thermal characteristics of a double-glazed external wall system with roll screen in cooling season

Tanaka, H. *et al. Building and Environment*, 2009, 44, (7), 1509–1516.

A double-skin system (double-glazed external wall) is an effective passive system that can be used to decrease solar heat gain into buildings. Detailed information on the thermal distribution of double-skin facades is necessary to design better systems that can provide thermal comfort and conserve energy. In this study, the three-dimensional thermal characteristics of double-skin facades that had the ventilation opening installed partially and were screened partially by the adjacent buildings were investigated by field measurements. To that end, field measurements were carried out on the double-skin exterior wall (9.4 m high and 27.0 m wide) installed in an atrium located in the west of an existing building during cooling period for typical summer conditions. Maximum air change rate of natural ventilation through the bottom opening up to the top opening is about 20–25 [1/h], the reduction ratio of total solar heat gain compared with those of non-natural ventilation is about 25%. The exhaust solar heat gain is about $100\,\mathrm{W/m^2}$ per inner glass surface area of the double-skin facades. Air temperature distribution of air space in the double skin was ranged from 30 to 44 °C, and heat gain difference ranged from 50 to $130\,\mathrm{W/m^2}$. The influence of the ventilation openings and the shade conditions on temperature distribution of double skin is found to be significant and the double-skin system was verified to reduce the cooling loads effectively.

10/00779 Thermal performance of natural airflow window in subtropical and temperate climate zones – a comparative study

Chow, T. *et al. Energy Conversion and Management*, 2009, 50, (8), 1884–1890.

Airflow window is highly useful in conserving building energy, and lessens the comfort problems caused by glazing. In this study, the thermal performance of a natural airflow window was examined through the use of a dynamic model, developed based on the integrated energy balance and airflow networks. The validity of the model was first tested by measured data obtained from a prototype installed at an environmental chamber. The application in the subtropical and temperate climate zones were then examined with the typical weather data of Hong Kong and Beijing. The findings confirmed that the natural airflow window can achieve substantial energy saving in both cities, and the reversible window frame is only required for Beijing, a location with hot summer and cold winter. The space cooling load via fenestration in Hong Kong, a subtropical city, can be reduced to 60% of the commonly used single absorptive glazing. In Beijing, as an example of the temperate climate, this can be reduced to 75% of the commonly used double glazing configuration in the summer period, and the space heat gain can be improved by 46% in the winter period.

10/00780 Three-layered absorptive glass mat separator with membrane for application in valve-regulated lead-acid batteries

Naidenov, V. *et al. Journal of Power Sources*, 2009, 192, (2), 730–735.
During charge and discharge of the lead-acid cell equal amounts of H_2SO_4 participate in the reactions at the two types of plates (electrodes). However, the charge and discharge reactions at the positive plates involve also 2 mol of water per every mole of reacted PbO_2. Consequently, a concentration difference appears in the electrolyte between the two electrodes (horizontal stratification), which affects the reversibility of the processes at the two electrodes and thus the cycle life of the battery. The present paper proposes the use of a three-layered absorptive glass mat (AGM) separator, the middle layer playing the role of a membrane that divides (separates) the anodic and cathodic electrolyte spaces, and controls the exchange rates of H_2SO_4, H^+ ions, O_2 and H_2O flows between the two electrode spaces. To be able to perform this membrane function, the thinner middle AGM layer (0.2 mm) is processed with an appropriate polymeric emulsion to acquire balanced hydrophobic/hydrophilic properties, which sustain constant H_2SO_4 concentration in the two electrode spaces during cycling. Three types of polymeric emulsions have been used for treatment of the membrane: (a) polyvinylpyrollidonestyrene (MPVS), (b) polyvinylpyrrolidone 'Luviskol' (MPVP), or (c) polytetrafluorethylene modified with Luviskol (MMAGM). It is established experimentally that the MMAGM membrane maintains equal acid concentration in the anodic and cathodic spaces (no horizontal stratification) during battery cycling and hence ensures longer cycle life performance.

13 ALTERNATIVE ENERGY SUPPLIES

Biofuels and bioconversion energy

10/00781 A probabilistic estimate of the frequency of mowing and baling days available in Oklahoma USA for the harvest of switchgrass for use in biorefineries

Hwang, S. *et al. Biomass and Bioenergy*, 2009, 33, (8), 1037–1045.
Determining the time available for required harvest operations is an essential prerequisite to optimizing lignocellulosic biomass (LCB) harvest costs. Estimating the number of days expected to be available for mowing and baling is difficult because agricultural field work is heavily weather dependent. Harvest costs are expected to constitute a large component of the cost to deliver LCB to a biorefinery. Harvest costs depend in part on the investment required in harvest machines, and this investment depends on the number of field workdays during the harvest window. Therefore, a reasonably precise estimate of the number of harvest days is necessary to determine the investment in harvest machines required to support a LCB biorefinery. The objective of this study was to determine the number of suitable field workdays in which switchgrass (*Panicum virgatum*) can be mowed and the number of days that mowed material can be baled. Empirical distributions of the days available for mowing and for baling switchgrass were determined for nine counties in the USA state of Oklahoma. Distributions were determined for each month and for two potential harvest seasons (short, October–December and extended, July–February). Beginning harvest in July and extending harvest through February would require only 37% as many baling machines as would be required for a short (October–December) harvest season. This potential reduction in harvest machine investment is consistent across location. An extended harvest season could reduce the investment required in harvest machines and the costs to deliver feedstock.

10/00782 Above ground standing biomass and carbon storage in village bamboos in North East India

Nath, A. J. *et al. Biomass and Bioenergy*, 2009, 33, (9), 1188–1196.
Bamboo forms an important component in the traditional landscape of north-east India. For biomass estimation of village bamboos of Barak Valley, north-east India, allometric relationships were developed by harvest method describing leaf, branch and culm biomass with DBH as an independent variable using a log linear model. The culm density of the stand was 8950 culms ha^{-1} during 2005 of which 67% of growing stock was represented by *Bambusa cacharensis*, 17.88% by *Bambusa vulgaris* and 15.12% by *Bambusa balcooa*. Above ground stand biomass was 121.51 t ha^{-1} of which 86% was contributed by culm component followed by branch (10%) and leaf (4%). With respect to species, *B. cacharensis* made up to 46% of total stand biomass followed by *B. vulgaris* (28%) and *B. balcooa* (26%). Carbon storage in the above ground biomass was 61.05 t ha^{-1}. Allocation of C was more in culm components (53.05 t ha^{-1}) than in branch (5.81 t ha^{-1}) and leaf (2.19 t ha^{-1}). Carbon storage in the litter floor mass was 2.40 t ha^{-1}, of which leaf litter made up the highest amount (1.37 t ha^{-1}) followed by sheath (0.86 t ha^{-1}) and branch (0.17 t ha^{-1}). Carbon stock in the soil up to 30 cm depth was 57.3 t ha^{-1}. Gross C stock in the plantation was estimated to be 120.75 t ha^{-1}. Carbon storage estimated in the bamboo stand of present study offers insights into the opportunity of village bamboos in the rural landscape for carbon storage through carbon sequestration. Management and utilization of village bamboos as a potential source of carbon sink by smallholder farmers are discussed in the context of their livelihood security and the Millennium Development Goals of the United Nations.

10/00783 Activity of solid catalysts for biodiesel production: a review

Zabeti, M. *et al. Fuel Processing Technology*, 2009, 90, (6), 770–777.
Heterogeneous catalysts are promising for the transesterification reaction of vegetable oils to produce biodiesel. Unlike homogeneous, heterogeneous catalysts are environmentally benign and could be operated in continuous processes. Moreover they can be reused and regenerated. However a high molar ratio of alcohol to oil, large amount of catalyst and high temperature and pressure are required when utilizing heterogeneous catalyst to produce biodiesel. In this paper, the catalytic activity of several solid base and acid catalysts, particularly metal oxides and supported metal oxides, was reviewed. Solid acid catalysts were able to do transesterification and esterification reactions simultaneously and convert oils with high amount of free fatty acids. However, the reaction rate in the presence of solid base catalysts was faster. The catalyst efficiency depended on several factors such as specific surface area, pore size, pore volume and active site concentration.

10/00784 Biodiesel from cotton seed oil and its effect on engine performance and exhaust emissions

Nabi, M. N. *et al. Applied Thermal Engineering*, 2009, 29, (11–12), 2265–2270.
The use of biodiesel is rapidly expanding around the world, making it imperative to fully understand the impacts of biodiesel on the diesel engine combustion process and pollutant formation. Biodiesel is known as the mono-alkyl-esters of long chain fatty acids derived from renewable feedstocks, such as, vegetable oils or animal fats, for use in compression ignition engines. Different parameters for the optimization of biodiesel production were investigated in the first phase of this study, while in the next phase of the study performance test of a diesel engine with neat diesel fuel and biodiesel mixtures were carried out. Biodiesel was made by the well known transesterification process. Cottonseed oil was selected for biodiesel production. Cottonseed is non-edible oil, thus food versus fuel conflict will not arise if this is used for biodiesel production. The transesterification results showed that with the variation of catalyst, methanol or ethanol, variation of biodiesel production was realized. However, the optimum conditions for biodiesel production are suggested in this paper. A maximum of 77% biodiesel was produced with 20% methanol in presence of 0.5% sodium hydroxide. The engine experimental results showed that exhaust emissions including carbon monoxide particulate matter and smoke emissions were reduced for all biodiesel mixtures. However, a slight increase in oxides of nitrogen emission was experienced for biodiesel mixtures.

10/00785 Biodiesel production from rapeseed deodorizer distillate in a packed column reactor

Liu, Y. and Wang, L. *Chemical Engineering and Processing: Process Intensification*, 2009, 48, (6), 1152–1156.
In this study, a technical method investigating biodiesel production in a column reactor packed with cation exchange resin from rapeseed oil deodorizer distillate (RODD) was addressed. The results showed that D002 cation exchange resin presented more efficiently catalytic activity than 002CR and 732 resins in a packed column reactor. Biodiesel yield achieved over 96% under the optimal conditions: D002 resin catalyst dosage 18 wt.% (based on oil weight), oil to methanol molar ratio 1:9, reaction temperature 60 °C, and reaction time 4 h. When the packed resin catalyst was recovered, biodiesel yield was over 88% after 10 repeated batch cycles (40 h). The comparison of biodiesel production in a packed column reactor and catalysed by traditional sulfuric acid from RODD was also studied. It was concluded that biodiesel synthesis in a packed column reactor would be a potential way for biodiesel production from RODD.

10/00786 Biodiesel synthesis combining pre-esterification with alkali catalyzed process from rapeseed oil deodorizer distillate

Liu, Y. *et al. Fuel Processing Technology*, 2009, 90, (7–8), 857–862.

A two-step technique combining pre-esterification catalysed by cation exchange resin with transesterification catalysed by base alkali was developed to produce biodiesel from rapeseed oil deodorizer distillate (RDOD). The free fatty acids in the feedstock were converted to methyl esters in the pre-esterification step using a column reactor packed with cation exchange resin. The acid value of oil was reduced from the initial 97.60 mg-KOH g^{-1} oil to 1.12 mg-KOH g^{-1} oil under the conditions of cation exchange resin D002 catalyst packed dosage 18 wt.% (based on oil weight), oil to methanol molar ratio 1:9, reaction temperature 60 °C, and reaction time 4 h. The biodiesel yield by transesterification was 97.4% in 1.5 h using 0.8 wt.% KOH as catalyst and a molar ratio of oil to methanol 1:4 at 60 °C. The properties of RDOD biodiesel production in a packed column reactor followed by KOH catalysed transesterification were measured up the standards of EN14214 and ASTM6751–03.

10/00787 Biofuels from waste fish oil pyrolysis: continuous production in a pilot plant

Wiggers, V. R. *et al. Fuel*, 2009, 88, (11), 2135–2141.

Fast pyrolysis of waste fish oil was performed in a continuous pyrolysis pilot plant. The experiment was carried out under steady-state conditions in which 10 kg of biomass was added at a feed rate of 3.2 kg h^{-1}. A bio-oil yield of 72–73% was obtained with a controlled reaction temperature of 525 °C. The bio-oil was distilled to obtain purified products with boiling ranges corresponding to light bio-oil and heavy bio-oil. These biofuels were characterized according to their physicochemical properties, and compared with the Brazilian-fuel specifications for conventional gasoline and diesel fuels. The results show that the fast pyrolysis process represents an alternative technique for the production of biofuels from waste fish oil with characteristics similar to petroleum fuels.

10/00788 Biogas energy from family-sized digesters in Uganda: critical factors and policy implications

Walekhwa, P. N. *et al. Energy Policy*, 2009, 37, (7), 2754–2762.

Dependence on fossil energy sources is increasingly becoming unsustainable due to ecological and environmental problems and rapid depletion. Biogas energy could augment these conventional energy sources but despite its advantages and the favourable conditions for its production, biogas energy use in Uganda remains low due to technical, economic and socio-cultural impediments. Based on primary data on households in central and eastern Uganda and the use of logistic regression, this study analyses factors affecting the adoption of biogas energy in Uganda. The empirical results suggest that the probability of a household adopting biogas technology increases with decreasing age of head of household, increasing household income, increasing number of cattle owned, increasing household size, male head of household and increasing cost of traditional fuels. In contrast, the likelihood of adoption decreases with increasing remoteness of household location and increasing household land area. Policy options and recommendations including educational and awareness campaigns on biogas benefits and successes, the provision of financial and non-financial incentives to households and establishment of an institutional framework could bolster wider biogas energy acceptance in Uganda.

10/00789 Characterization of organic compounds and molecular tracers from biomass burning smoke in South China I: broad-leaf trees and shrubs

Wang, Z. *et al. Atmospheric Environment*, 2009, 43, (19), 3096–3102.

Biomass burning smoke constituents are worthy of concern due to its influence on climate and human health. The organic constituents and distributions of molecular tracers emitted from burning smoke of six natural vegetations including monsoon evergreen broad-leaf trees and shrubs in South China were determined in this study. The gas and particle samples were collected and analysed by gas chromatography–mass spectrometry. The major organic components in these smoke samples are methoxyphenols from lignin and saccharides from cellulose. Polycyclic aromatic hydrocarbons (PAHs) are also present as minor constituents. Furanose, pyranose and their dianhydrides are the first reported in the biomass burning smoke. Some unique biomarkers were detected in this study which may be useful as specific tracers. The corresponding tracer/OC ratios are used as indicators for the two types of biomass burning. U/R (1.06–1.72) in the smoke samples may be used as parameters to distinguish broad-leaf trees and shrubs from fossil fuel. Other useful diagnostic ratios such as methylphenanthrene to phenanthrene (MPhe/Phe), phenanthrene to phenanthrene plus anthracene (Phe/(Phe + Ant)) and fluoranthene to fluoranthene plus pyrene (Flu/(Flu + Pyr)) and octadecenoic acid/OC are also identified in this study. These results are useful in efforts to better understand the emission characterization of biomass burning in South China and the contribution of regional biomass burning to global climate change.

10/00790 Comparison of the univariate and multivariate methods in the optimization of experimental conditions for determining Cu, Pb, Ni and Cd in biodiesel by GFAAS

Lobo, F. A. *et al. Fuel*, 2009, 88, (10), 1907–1914.

Experimental design was used as a tool to define the optimum pyrolysis and atomization temperatures for four analytes (Cu, Pb, Ni and Cd) in biodiesel samples. Two chemical modifiers (Pd + Mg and W) and two distinct sample preparation procedures (microemulsion and wet digestion in a focused microwave system) were also investigated. The pyrolysis and atomization temperatures were optimized using 2^4 factorial design for Cu, Pb, Ni and Cd, with 16 assays carried out for each analyte. The results for Cu and Pb indicated that variables of sample preparation for digestion by focused microwave was the most important one for both analytes. The pyrolysis and atomization temperatures applied were 1000 °C and 2200 °C for Cu and 500 °C and 2000 °C for Pb. None of the variables analysed here were important for Ni, and the pyrolysis and atomization temperatures chosen for this element were 800 °C and 2300 °C. A different factorial design was used for Cd. The variables of medium and modifier were not important for this element, and the lowest temperatures, Tp-500 °C and Ta-1400 °C, were chosen based on this second design. The importance of factorial design in the simultaneous optimization of several variables studied by GFAAS was confirmed, for it involves fewer experiments and hence, lower costs, greater speed and higher efficiency.

10/00791 Development of new catalytic systems for upgraded bio-fuels production from bio-crude-oil and biodiesel

Yakovlev, V. A. *et al. Catalysis Today*, 2009, 144, (3–4), 362–366.

The investigation of upgraded bio-fuels production processes was carried out via the development of efficient catalysts for oxy-organic hydrodeoxygenation (HDO) processes. It was found that Ni–Cu catalysts are more attractive than single Ni catalysts in HDO under mild conditions. Copper facilitates the nickel oxide reduction at temperatures lower than 300 °C. Moreover, copper prevents methanization of oxy-organics at 280–350 °C. The catalyst supports play also a key role in hydrotreatment of oxygen-containing compounds. Screening of catalyst supports showed that CeO_2 and ZrO_2 are most effective in the target processes because of possible additional activation of oxy-compounds on the support surface. The prepared catalysts have non-sulfided nature and can be used for upgrading of bioliquids with a low sulfur content.

10/00792 Dilute acid hydrolysis of lignocellulosic biomass

Lenihan, P. *et al. Chemical Engineering Journal*, 2009, 156, (2), 395–403.

The overall aim of this work was to establish the optimum conditions for acid hydrolysis of hemicellulosic biomass in the form of potato peel. The hydrolysis reaction was undertaken in a 1-litre high-pressure pilot batch reactor using dilute phosphoric acid. Analysis of the decomposition rate of hemicellulosic biomass (namely cellulose, hemicellulose and lignin) was undertaken using HPLC of the reaction products namely, five- and six-carbon sugars. Process parameters investigated included, reactor temperature (from 135 to 200 °C) and acid concentration [from 2.5% (w/w) to 10% (w/w)]. Analysis of the reactor products indicated that high conversion of cellulose to glucose was apparent although arabinose conversion was quite low due to thermally un-stability. However, an overall sugar yield is 82.5% was achieved under optimum conditions. This optimum yield was obtained at 135 °C and 10% (w/w) acid concentration. 55.2 g sugar/100 g dry potato peel is produced after a time of 8 min. The work indicates that the use of potato peel may be a feasible option as a feed material for the production of sugars for biofuel synthesis, due its low cost and high sugar yields.

10/00793 Effects of particle size on the fast pyrolysis of oil mallee woody biomass

Shen, J. *et al. Fuel*, 2009, 88, (10), 1810–1817.

This study aims to investigate the effects of biomass particle size (0.18–5.6 mm) on the yield and composition of bio-oil from the pyrolysis of Australian oil mallee woody biomass in a fluidized-bed reactor at 500 °C. The yield of bio-oil decreased as the average biomass particle size was increased from 0.3 to about 1.5 mm. Further increases in biomass particle size did not result in any further decreases in the bio-oil yield. These results are mainly due to the impact of particle size in the production of lignin-derived compounds. Possible inter-particle interactions between bio-oil vapour and char particles or homogeneous reactions in vapour phases were not responsible for the decreases in the bio-oil yield. The bio-oil samples were characterized with thermogravimetric analysis, UV-fluorescence spectroscopy, Karl–Fischer titration as well as precipitation in cold water. It was found that the yields of light bio-oil fractions increased and those of heavy bio-oil fractions decreased with increasing biomass particle size. The formation of pyrolytic water at low temperatures (<500 °C) is not greatly affected by temperature or particle size. It is believed that decreased heating rates experienced by large particles are a major factor responsible for the lower bio-oil yields from large particles and for the changes in the overall composition of resulting oils. Changes in biomass cell structure during grinding may also influence the yield and composition of bio-oil.

10/00794 Enzymatic saccharification of dilute acid pretreated saline crops for fermentable sugar production

Zheng, Y. *et al. Applied Energy*, 2009, 86, (11), 2459–2465.
Four saline crops [athel (*Tamarix aphylla* L), eucalyptus (*Eucalyptus camaldulensis*), Jose Tall Wheatgrass (*Agropyron elongatum*), and Creeping wild ryegrass (*Leymus triticoides*)] that are used in farms for salt uptake from soil and drainage irrigation water have the potential for fuel ethanol production because they do not need arable land. Dilute sulfuric acid pretreatment and enzymatic hydrolysis were conducted to select the optimum pretreatment conditions and the best saline crop for further enzymatic hydrolysis research. The optimum dilute acid pretreatment conditions included $T = 165\,^{\circ}\mathrm{C}$, $t = 8$ min, and sulfuric acid concentration = 1.4% (w/w). Creeping wild ryegrass was decided to be the best saline crop. Solid loading, cellulase and β-glucosidase concentrations had significant effects on the enzymatic hydrolysis of dilute acid pretreated creeping wild ryegrass. Glucose concentration increased by 36 mg/mL and enzymatic digestibility decreased by 20% when the solid loading increased from 4 to 12%. With 8% solid loading, enzymatic digestibility increased by over 30% with the increase of cellulase concentration from 5 to 15 FPU/g-cellulose. Under given cellulase concentration of 15 FPU/g-cellulose, 60% increase of enzymatic digestibility of pretreated creeping wild ryegrass was obtained with the increase of β-glucosidase concentration up to 15 CBU/g-cellulose. With a high solid loading of 10%, fed-batch operation generated 12% and 18% higher enzymatic digestibility and glucose concentration, respectively, than batch process.

10/00795 How sustainable are biofuels? Answers and further questions arising from an ecological footprint perspective

Stoeglehner, G. and Narodoslawsky, M. *Bioresource Technology*, 2009, 100, (16), 3825–3830.
By using biofuels, bioproductive land is devoted to supply energy. As the bioproductive land area on our planet is confined and actually decreasing, biofuels compete against other demands like the production of food, industrial resources, nature conservation, etc. This not only results in higher prices for agricultural and forestry products, but also increases environmental pressures. The aim of this paper is to clarify if and to which extent biofuels might be sustainable by applying modified calculation methods of the ecological footprint. It can be concluded that biofuels can offer huge environmental benefits compared to fossil fuels. Yet, if and to which extent biofuel production is sustainable depends on the amount of land available and, therefore, can only be decided in a regional context. Ecological footprinting can significantly support these regional decision-making processes.

10/00796 Land substitution effects of biofuel side products and implications on the land area requirement for EU 2020 biofuel targets

Özdemir, E. D. *et al. Energy Policy*, 2009, 37, (8), 2986–2996.
The provision of biofuels today is based on energy crops rather than residual biomass, which results in the requirement of agricultural land area. The side products may serve as animal feed and thus prevent cultivation of other feedstock and the use of corresponding land area. These effects of biofuel provision have to be taken into account for a comprising assessment of land area requirement for biofuel provision. Between 18.5 and 21.1 Mio. hectares (ha) of land area is needed to meet the EU 2020 biofuel target depending on the biofuel portfolio when substitution effects are neglected. The utilization of the bioethanol side products, distiller's dried grain and solubles (DDGS) and pressed beet slices may save up to 0.7 Mio. ha of maize cultivation area in the EU. The substitution effect due to the utilization of biodiesel side products (oil cakes of rape, palm and soy) as animal feed may account for up to 7.1 Mio. ha of soy cultivation area in Brazil. The results show that the substitution of land area due to use of side products might ease the pressures on land area requirement considerably and should therefore not be neglected in assessing the impacts of biofuel provision worldwide.

10/00797 Metabolic engineering of cyanobacteria for ethanol production

Dexter, J. and Fu, P. *Energy & Environment Science*, 2009, 2, (2), 857–864.
Currently most of the bioethanol production is from the fermentation of agricultural crops and residues. There is much debate concerning the cost effectiveness and energy efficiency of such biomass based ethanol production processes. In this paper the authors report the creation of a *Synechocystis* sp. PCC 6803 strain that can photoautotrophically convert CO_2 to bioethanol. Transformation was performed using a double homologous recombination system to integrate the pyruvate decarboxylase (*pdc*) and alcohol dehydrogenase II (*adh*) genes from obligately ethanol producing *Zymomonas mobilis* into the *Synechocystis* PCC 6803 chromosome under the control of the strong, light driven *psbAII* promoter. PCR based assay and ethanol production assay were used to screen for stable transformants. A computerized photobioreactor system was established for the experimental design and data acquisition for the analysis of the cyanobacterial cell cultures and ethanol production. The system described here shows an average yield of 5.2 mmol OD_{730} unit^{-1} litre^{-1} day^{-1} with no required antibiotic/selective agent.

10/00798 Methodology for optimization of distributed biomass resources evaluation, management and final energy use

Alfonso, D. *et al. Biomass and Bioenergy*, 2009, 33, (8), 1070–1079.
A methodology has been developed to assess optimal management and energy use of distributed biomass resources, where logistics is a main factor but other features must be also considered: biomass resources properties (quantity, quality, seasonality and availability), plant size effect, available technologies for power, heat and solid biofuels generation, CO_2 emissions balance and quantification of potential biofuel consumers. This methodology provides a quantification and characterization of biomass resources, a list of optimal locations from logistic point of view and the necessary data to perform detailed technical, economic and environmental analysis of the different biomass energy use options. It has been applied to three districts of the Valencian region in Spain and main results and conclusions are also included in this paper.

10/00799 Net energy value of maize ethanol as a response to different climate and soil conditions in the southeastern USA

Persson, T. *et al. Biomass and Bioenergy*, 2009, 33, (8), 1055–1064.
A recent increase in the demand for bio-ethanol has sparked maize production in the USA and other countries across the world. The net energy value (NEV), i.e. the energy output in ethanol and co-products after accounting for energy input requirements in the production chain of ethanol, is a measure of its sustainability. Grain yield of maize, which varies substantially across different climate and soil conditions, greatly impacts the ethanol NEV. The objectives of this study were to determine: (i) the NEV of ethanol produced from maize grown in four production regions in the southeastern USA and, (ii) the specific impact of local soil variability under the same climate conditions within the four regions on the NEV of maize-ethanol. Maize yield was simulated with the Cropping System Model (CSM)-CERES-Maize model for soil and weather conditions, and management practices representing Bulloch, Floyd, Laurens and Mitchell counties, Georgia, USA. The calculation of ethanol NEV took into account the energy inputs and outputs of the entire ethanol production chain, and was based on the crop simulations. There were statistically significant differences in ethanol NEV among the counties, and within counties due to local soil variability. Differences in ethanol NEV among counties were partially due to different transportation distances. Based on the results of this study, it was concluded that maize-ethanol NEV can be increased by accounting for the soil and climate factors in the feedstock production and by locating ethanol-processing facilities in regions with soil and climate conditions that are favourable for ethanol-maize production.

10/00800 Perceived importance of fuel characteristics and its match with consumer beliefs about biofuels in Belgium

Van de Velde, L. *et al. Energy Policy*, 2009, 37, (8), 3183–3193.
Consumer consciousness concerning the environment has increased and become a major factor in purchasing behaviour. Consumer research to understand and influence the adoption of green technologies and products is therefore important. This paper investigates the beliefs of Belgian consumers concerning the use of biofuels and identifies four consumer segments based on the perceived importance of different fuel characteristics. To convince the performance-oriented consumers to use biofuels, information about these fuels has to stress their quality and performance standards. The society-oriented cluster attaches great importance to environmental friendliness, odour, production origin, the opportunity to decrease energy dependency and job creation. To persuade the environment-oriented consumers low odour, beneficial environmental influence and quality assurance of biofuels have to be emphasized. The convenience-oriented consumers will be the most difficult to persuade to use biofuels. They need to be convinced that every vehicle can drive with biofuel blends without the need for engine modifications. Concerns relating to the price and perceived low availability of biofuels at fuel stations are major obstacles for all consumers involved in this study.

10/00801 Preparation and characterization of activated carbon from wood *via* microwave-induced $ZnCl_2$ activation

Wang, T. *et al. Carbon*, 2009, 47, (7), 1880–1885.

Microwave heating, in which $ZnCl_2$ was used as activation agent and heating carrier, has been successfully used to prepare activated carbon from wood. The process is simple and only takes a few minutes. The pore structure and surface area of the as-prepared carbon materials can be tuned by simply changing the ratio of $ZnCl_2$ to wood and the microwave heating time.

10/00802 Recent trends in global production and utilization of bio-ethanol fuel

Balat, M. and Balat, H. *Applied Energy*, 2009, 86, (11), 2273–2282.

Bio-fuels are important because they replace petroleum fuels. A number of environmental and economic benefits are claimed for bio-fuels. Bio-ethanol is by far the most widely used bio-fuel for transportation worldwide. Production of bio-ethanol from biomass is one way to reduce both consumption of crude oil and environmental pollution. Using bio-ethanol blended gasoline fuel for automobiles can significantly reduce petroleum use and exhaust greenhouse gas emission. Bio-ethanol can be produced from different kinds of raw materials. These raw materials are classified into three categories of agricultural raw materials: simple sugars, starch and lignocellulose. Bio-ethanol from sugar cane, produced under the proper conditions, is essentially a clean fuel and has several clear advantages over petroleum-derived gasoline in reducing greenhouse gas emissions and improving air quality in metropolitan areas. Conversion technologies for producing bio-ethanol from cellulosic biomass resources such as forest materials, agricultural residues and urban wastes are under development and have not yet been demonstrated commercially.

10/00803 Review on biofuel oil and gas production processes from microalgae

Amin, S. *Energy Conversion and Management*, 2009, 50, (7), 1834–1840.

Microalgae, as biomass, are a potential source of renewable energy, and they can be converted into energy such as biofuel oil and gas. This paper presents a brief review on the main conversion processes of microalgae becoming energy. Since microalgae have high water content, not all biomass energy conversion processes can be applied. By using thermochemical processes, oil and gas can be produced, and by using biochemical processes, ethanol and biodiesel can be produced. The properties of the microalgae product are almost similar to those of offish and vegetable oils, and therefore, it can be considered as a substitute of fossil oil.

10/00804 Synthesis of biodiesel from cottonseed oil and methanol using a carbon-based solid acid catalyst

Shu, Q. *et al. Fuel Processing Technology*, 2009, 90, (7–8), 1002–1008.

A carbon-based solid acid catalyst was prepared by the sulfonation of carbonized vegetable oil asphalt and used to catalyse the transesterification of methanol with cottonseed oil. This catalyst was characterized by scanning electron microscopy/energy dispersive spectroscopy, BET surface area and pore size measurement, thermogravimetry analysis and Fourier transform infrared spectroscopy. The sulfonated multi-walled carbon nanotubes (s-MWCNTs) was also prepared and used to catalyse the same transesterification as the asphalt catalyst. The asphalt-based catalyst shows higher activity than the s-MWCNTs for the production of biodiesel, which may be correlated to its high acid site density, its loose irregular network and large pores can provide more acid sites for the reactants. The conversion of cottonseed oil 89.93% was obtained (using the asphalt-based catalyst) when the methanol/cottonseed oil molar ratio was 18.2, reaction temperature at 260 °C, reaction time 3.0 h and catalyst/cottonseed oil mass ratio of 0.2%. Also, it can be re-used. The sulfonated polycyclic aromatic hydrocarbons provide an electron-withdrawing function to keep the acid site stable. The catalyst can substantially reduce energy consumption and waste generation in the production of biodiesel.

10/00805 Synthetic and natural waters disinfection using natural solar radiation in a pilot plant with CPCs

Gomes, A. I. *et al. Catalysis Today*, 2009, 144, (1–2), 56–61.

Solar disinfection of synthetic and natural waters from the Douro River, northern Portugal was studied in a pilot plant with compound parabolic collectors. Inactivation of *Enterococcus faecalis* was slower than *Escherichia coli* possibly due to the cell wall composition of the Gram-positive and Gram-negative bacteria, respectively. The high content of peptidoglycan, teichoic acids, polysaccharides, and peptidoglycolipids, in *E. faecalis* cell wall, when compared with *E. coli*, acts as a protective coating. Higher inactivation rate constants were obtained for higher initial bacteria concentrations; however a greater dose of UV energy was required. The flow rate effect in disinfection of synthetic waters was negligible. However, for natural waters with low bacteria contamination, the effect of the mechanical stress on the inactivation increased with the flow rate. Competition for the reactive oxidant radicals was observed in binary systems, containing similar concentrations of *E. coli* and *E. faecalis*. No bacterial regrowth was observed for *E. faecalis* in synthetic waters. Oppositely, regrowth occurred for natural waters. This behaviour can be due to the natural water chemical composition, with the presence of various organic and inorganic species.

10/00806 Technical and economical analyses of combined heat and power generation from distillers grains and corn stover in ethanol plants

Wang, L. *et al. Energy Conversion and Management*, 2009, 50, (7), 1704–1713.

The technical and economical feasibilities of a novel integrated biomass gasification and fuel cell combined heat and power (CHP) system were analysed for supplying heat and power in an ethanol plant from distillers grains (DG) and corn stover. In a current dry-grind plant with an annual production capacity of 189 million litres (50 million gallons) of ethanol, the energy cost for ethanol production using natural gas at a price of 6.47 US$/GJ for processing heat and commercial grid at a price of 0.062 US$/kWh for electrical power supply was 0.094 US$/litre. If the integrated CHP system using wet DG with 64.7% moisture on a wet basis at 105 US$/dry tonne and corn stover with 20% moisture at 30 US$/dry tonne as feedstock was used to supply heat and power in the ethanol plant, the energy costs for ethanol production would be 0.101 US$/litre and 0.070 US$/litre, which are 107% and 75% of the current energy cost for ethanol production, respectively. To meet the demand of processing heat and power in the ethanol plant, the integrated CHP system required 22.1 dry tonnes of corn stover with 20% moisture or 14.5 dry tonnes of DG with 64.7% moisture on a wet basis per hour, compared with the available 18.8 dry tonnes of DG per hour in the ethanol plant. High-value chemicals such as policosanols, phytosterols and free fatty acids can be extracted out of the raw DG to reduce the cost of DG as a feedstock of the integrated CHP system. The energy cost for ethanol production using the integrated CHP system with corn stover and DG as the feedstock for supplying heat and power can be reduced further by increasing ethanol production scale, decreasing the moisture content of biomass feedstock, and decreasing thermal energy to electricity output ratio of the CHP system. In terms of the energy efficiency of the integrated CHP system and the energy cost for ethanol production, the moisture content of the feedstock going into the integrated CHP should be lower than 70% on a wet basis.

10/00807 Thermo-economic analysis for the optimal conceptual design of biomass gasification energy conversion systems

Brown, D. *et al. Applied Thermal Engineering*, 2009, 29, (11–12), 2137–2152.

This study addresses the thermo-economic assessment of a mid-scale (20 $MW_{th,wood}$) wood gasification, gas cleaning and energy conversion process, with particular attention given to electricity generation costs and tar control. Product distributions were estimated with a parametric stoichiometric equilibrium model calibrated using atmospheric air gasification data. A multi-objective optimization problem was defined for a superstructure of alternative energy flow diagrams for each processing step. The trade-off between total investment costs and the exergy efficiency of electricity production was obtained, and analysed to identify operating conditions that minimize tar formation to prevent equipment fouling. The use of air, oxygen or steam fluidized bed gasifiers, closed coupled to an internal combustion engine combined cycle (ICE-CC) requiring cold gas cleaning, or gas turbine combined cycle (GT-CC) requiring hot gas cleaning have been considered. The operating conditions that maximize ICE-CC efficiency with cold gas cleaning (low pressure and high temperatures) also favour minimal tar formation. For GT-CC tar concentrations are higher, but this should not be of concern provided that hot gas cleaning can effectively prevent tar condensation. The trade-off appears to be optimal for steam gasification, with minimal specific costs of 2.1 €/W_e for GT-CC, and 2.7 €/W_e for ICE-CC. However, further calibration of the reaction model is still needed to properly assess product formation for other oxidants than air, and to properly take account of the impact of pressure on product distributions. For air gasification, the minimal specific cost of GT-CC is 2.5 €/W_e, and that of ICE-CC 3.1 €/W_e.

10/00808 Trace elements in Turkish biomass fuels: ashes of wheat straw, olive bagasse and hazelnut shell

Bakisgan, C. *et al. Fuel*, 2009, 88, (10), 1842–1851.

Ash contents of wheat straw, olive bagasse and hazelnut shells were 7.9%, 3.9%, 1.2%, respectively, which seemed to be within the average values of ash of biomass. The microstructure of ashes included smooth, polygonal, granular and molten drop structures. A large percentage of particles present in ashes are commonly ~1–20 μm in size. SEM/EDS analyses performed on the major ash forming elements in different ashes indicated that Si, Ca, K and Mg and P were generally the most abundant species. Trace element levels in ash samples of various biomass types such as hazelnut shell, wheat straw, olive bagasse were analysed using ICP spectroscopy. The elements determined were some of those considered being of great environmental concern such as, Cr, Mn, Fe, Co, Ni, Cu, Zn, Pb. In all of the ashes studied Fe had the highest concentration among other trace elements, Mn was the second element that exhibited higher concentrations. The order of concentration of elements in the ashes from the highest to the lowest values was as follows: Fe > Mn > Zn > Cu > Ni > Cr > Pb > Co.

10/00809 Transesterification of rapeseed oil for the production of biodiesel using homogeneous and heterogeneous catalysis

Georgogianni, K. G. *et al. Fuel Processing Technology*, 2009, 90, (7–8), 1016–1022.

This study considered the transesterification reaction of rapeseed oil with methanol, in the presence of alkaline catalysts, either homogeneous (NaOH) or heterogeneous (Mg MCM-41, Mg–Al Hydrotalcite, and K^+ impregnated zirconia), using low frequency ultrasonication (24 kHz) and mechanical stirring (600 rpm) for the production of biodiesel fuel. Selection of heterogeneous catalysts was based on a combination of their porosity and surface basicity. Their characterization was carried out using X-ray diffraction (XRD), Nitrogen adsorption–desorption porosimetry and scanning electron microscopy (SEM) with energy dispersive spectroscopy (EDS). The activities of the catalysts were related to their basic strength. Mg–Al hydrotalcite showed particularly the highest activity with conversion reaching 97%). The activity of ZrO_2 in the transesterification reaction increased as the catalyst was doped with more potassium cations, becoming thus more basic. Use of ultrasonication significantly accelerated the transesterification reaction compared to the use of mechanical stirring (5 h vs 24 h). Given the differences in experimental design, it can be concluded that the homogeneous catalyst accelerated significantly the transesterification reaction, as compared to all heterogeneous catalysts, using both mechanical stirring (15 min vs 24 h) and ultrasonication (10 min vs 5 h). However, the use of homogeneous base catalysts requires neutralization and separation from the reaction mixture leading to a series of environmental problems related to the use of high amounts of solvents and energy. Heterogeneous solid base catalysts can be easily separated from the reaction mixture by simple filtration, they are easily regenerated and bear a less corrosive nature, leading to safer, cheaper and more environment-friendly operations.

10/00810 Using cheese whey for hydrogen and methane generation in a two-stage continuous process with alternative pH controlling approaches

Venetsaneas, N. *et al. Bioresource Technology*, 2009, 100, (15), 3173–3177.

This study focuses on the exploitation of cheese whey as a source for hydrogen and methane, in a two-stage continuous process. Mesophilic fermentative hydrogen production from undiluted cheese whey was investigated at a hydraulic retention time (HRT) of 24 h. Alkalinity addition ($NaHCO_3$) or an automatic pH controller were used, to maintain the pH culture at a constant value of 5.2. The hydrogen production rate was 2.9 ± 0.2 L/Lreactor/d, while the yield of hydrogen produced was approximately 0.78 ± 0.05 mol H_2/mol glucose consumed, with alkalinity addition, while the respective values when using pH control were 1.9 ± 0.1 L/Lreactor/d and 0.61 ± 0.04 mol H_2/mol glucose consumed. The corresponding yields of hydrogen produced were 2.9 L of H_2/L cheese whey and 1.9 L of H_2/L cheese whey, respectively. The effluent from the hydrogenogenic reactor was further digested to biogas in a continuous mesophilic anaerobic bioreactor. The anaerobic digester was operated at an HRT of 20d and produced approximately 1 L CH_4/d, corresponding to a yield of 6.7 L CH_4/L of influent. The chemical oxygen demand (COD) elimination reached 95.3% demonstrating that cheese whey could be efficiently used for hydrogen and methane production, in a two-stage process.

Geothermal energy

10/00811 Carbon dioxide degassing and thermal energy release in the Monte Amiata volcanic-geothermal area (Italy)

Frondini, F. *et al. Applied Geochemistry*, 2009, 24, (5), 860–875.

The quaternary volcanic complex of Mount Amiata is located in southern Tuscany (Italy) and represents the most recent manifestation of the Tuscan Magmatic Province. The region is characterised by a large thermal anomaly and by the presence of numerous CO_2-rich gas emissions and geothermal features, mainly located at the periphery of the volcanic complex. Two geothermal systems are located, at increasing depths, in the carbonate and metamorphic formations beneath the volcanic complex. The shallow volcanic aquifer is separated from the deep geothermal systems by a low permeability unit (Ligurian Unit). A measured CO_2 discharge through soils of 1.8×10^9 mol a^{-1} shows that large amounts of CO_2 move from the deep reservoir to the surface. A large range in $\delta^{13}C_{TDIC}$ (−21.07 to +3.65) characterises the waters circulating in the aquifers of the region and the mass and isotopic balance of TDIC allows distinguishing a discharge of 0.3×10^9 mol a^{-1} of deeply sourced CO_2 in spring waters. The total natural CO_2 discharge (2.1×10^9 mol a^{-1}) is slightly less than minimum CO_2 output estimated by an indirect method (2.8×10^9 mol a^{-1}), but present-day release of 5.8×10^9 mol a^{-1} CO_2 from deep geothermal wells may have reduced natural CO_2 discharge. The heat transported by groundwater, computed considering the increase in temperature from the infiltration area to the discharge from springs, is of the same order of magnitude, or higher, than the regional conductive heat flow (>200 mW m^{-2}) and reaches extremely high values (up to 2700 mW m^{-2}) in the north-eastern part of the study area. Heat transfer occurs mainly by conductive heating in the volcanic aquifer and by uprising gas and vapour along fault zones and in those areas where low permeability cover is lacking. The comparison of CO_2 flux, heat flow and geological setting shows that near surface geology and hydrogeological setting play a central role in determining CO_2 degassing and heat transfer patterns.

10/00812 Geothermal power production from abandoned oil wells

Davis, A. P. *et al. Energy*, 2009, 34, (7), 866–872.

A simulation for the determination of geothermal power production from abandoned oil wells by injecting and retrieving a secondary fluid was performed. The analysis takes into consideration local geothermal gradients and typical well depths and pipe diameters. Isobutane is chosen as the secondary fluid, which is injected in the well at moderate pressures and allowed to heat up and produce vapour. The computational model that was developed takes into account mass, energy, and momentum conservation equations for the well flow, and the simulation helps determine the state of the fluid from injection to retrieval. It is observed that the operation of such systems attains a maximum power that depends on the temperature of the well bottom and the injection pressure. In general, 2–3 MW of electric power may be produced from wells that are typical in the South Texas region.

10/00813 Multi-objective optimization of a vertical ground source heat pump using evolutionary algorithm

Sayyaadi, H. *et al. Energy Conversion and Management*, 2009, 50, (8), 2035–2046.

Thermodynamic and thermoeconomic optimization of a vertical ground source heat pump system has been studied. A model based on the energy and exergy analysis is presented here. An economic model of the system is developed according to the total revenue requirement method. The objective functions based on the thermodynamic and thermoeconomic analysis are developed. The proposed vertical ground source heat pump system including eight decision variables is considered for optimization. An artificial intelligence technique known as evolutionary algorithm has been utilized as an optimization method. This approach has been applied to minimize either the total levelized cost of the system product or the exergy destruction of the system. Three levels of optimization including thermodynamic single objective, thermoeconomic single objective and multi-objective optimizations are performed. In multi-objective optimization, both thermodynamic and thermoeconomic objectives are considered, simultaneously. In the case of multi-objective optimization, an example of decision-making process for selection of the final solution from available optimal points on Pareto frontier is presented. The results obtained using the various optimization approaches are compared and discussed. Further, the sensitivity of optimized systems to the interest rate, to the annual number of operating hours and to the electricity cost are studied in detail.

10/00814 New energy and exergy parameters for geothermal district heating systems

Coskun, C. *et al. Applied Thermal Engineering*, 2009, 29, (11–12), 2235–2242.

This paper introduces four new parameters, namely energetic renewability ratio, exergetic renewability ratio, energetic reinjection ratio, and exergetic reinjection ratio for geothermal district energy systems. These parameters are applied to Edremit Geothermal District Heating System (GDHS) in Balikesir, Turkey for daily, monthly and yearly assessments and their variations are studied. In addition, the actual data are regressed to obtain some applied correlations for practical use. Some results follow: (i) Both energetic and exergetic renewability ratios decrease with decreasing temperature in heating season and increasing temperature in the summer. (ii) Both energetic and exergetic reinjection ratios increase with decreasing temperature for heating season and increase with increasing temperature for summer season.

10/00815 Open-loop groundwater heat pumps development for large buildings: A case study

Lo Russo, S. and Civita, M. V. *Geothermics*, 2009, 38, (3), 335–345.

A study of the feasibility of providing the heating and cooling needs of the new, large commercial building near Turin, Italy, by means of an open-loop indirect groundwater heat pump (GWHP) system is described. A finite element subsurface flow and transport simulator (FEFLOW) was used to investigate possible configurations of extraction and injection wells for five different scenarios. Modelling results confirmed the hydrogeological capacity of the site to provide the necessary amount of groundwater and associated energy with limited environmental impact. Injection of warmer (or cooler) water in the aquifer creates a thermal plume whose dimensions and geometry depend on the properties of the subsurface formations, particularly their thermal dispersivity values. The study suggests that there are several possible well configurations that could support the GWHP system without adversely affecting the aquifer.

10/00816 Production engineering in geothermal technology: a review

Gallup, D. L. *Geothermics*, 2009, 38, (3), 326–334.

Geothermal energy is abundant and renewable, but only a very small fraction can currently be converted commercially to electricity and heating value with today's technology. In recent years, the installed geothermal capacity worldwide has more than doubled. The increase in the use of geothermal energy is the result of a multi-disciplinary effort. Highlighted are some production engineering advances that have played a significant part in making geothermal a competitive renewable energy resource.

10/00817 Transient development of flow and temperature fields in an underground thermal storage tank under various charging modes

Papanicolaou, E. and Belessiotis, V. *Solar Energy*, 2009, 83, (8), 1161–1176.

The flow and heat transport phenomena developing in a real-scale, underground hot-water storage tank intended for central solar systems and made of concrete walls are studied numerically and experimentally. The cubic tank with a volume of 8 m^3 has been equipped with two linear diffusers extending over its entire width. For the numerical computations, charging of the tank at a constant flow rate and three different inlet-temperature histories was considered. One of these corresponded to a simple constant value, a second one to solar-collector heating and the third one to electric heating. In the last case experimental data were also obtained. The charging process was simulated by dynamic models based on the multinode and plug-flow approaches, as well as two-dimensional (2D) computational fluid dynamics (CFD), for which both low-Re k-ε and two-layer turbulence models were used. The distinct features of the flow and temperature fields for each charging mode as obtained from the models have been analysed and compared to each other. For the electric heating case, preliminary comparisons between models and experiments were made, showing good qualitative agreement, while quantitative agreement was achieved only for parts of the entire transient process. The effects of turbulence-model choice and water-surface heat losses were also demonstrated and found to be important factors in the modelling procedure.

Solar energy

10/00818 A mathematical procedure to estimate solar absorptance of shallow water ponds

Wu, H. *et al. Energy Conversion and Management*, 2009, 50, (7), 1828–1833.

In this article, a mathematical procedure is developed for estimating solar absorption of shallow water ponds with different pond floor based on the fact that the solar radiation trapped inside the water layer undergoes multiplicative reflection and absorption and on that the solar absorption of water is selective. Theoretical model indicates that the solar absorption of a water pond is related to the reflectivity of the pond floor, the solar spectrum and the water depth. To validate the mathematical model, a concrete water pond measuring 3 m × 3 m × 0.24 m was constructed. Experimental results indicate that solar reflectivity calculated based on the mathematical model proposed in this work were in good agreement with those measured. For water ponds with a water-permeable floor, such as concrete floor, theoretical calculations of the solar absorptance of a water pond should be done based on the reflectivity of full wet floor, whereas for water ponds with a non-water-permeable floor, theoretical calculations should be done based on the fact that solar reflection on the floor is neither perfect specular reflection nor prefect isotropic diffuse reflection. Results of numerical calculation show that theoretical calculations of solar absorption of a water pond by dividing solar spectrum into six bands were pretty agreement with those by dividing solar spectrum into 20 bands.

10/00819 A new topology to mitigate the effect of shading for small photovoltaic installations in rural sub-Saharan Africa

Ubisse, A. and Sebitosi, A. *Energy Conversion and Management*, 2009, 50, (7), 1797–1801.

Many field researchers have in the past grappled with the problems of energy loss and panel damage as a result of shading and staining of PV panels after installation. A number of solutions have been proposed to try and minimize the effects of this problem in the field. The problem with all these solutions is that they address inter-panel connection topologies for very large installations. No particular attention has been paid to the topologies of individual panels. In sub-Saharan Africa most installations are single panel solar home systems and therefore small shading can result in an entire installation being disabled. This paper aims to study the effect of shading and staining on photovoltaic modules and propose a new topology that will reduce the effect of shading on the performance of individual photovoltaic modules.

10/00820 Additional layer of the multi-walled carbon-nanotubes increases the photo-current of a *poly* (3-hexylthiophene)-sensitised solar cell

Furuta, A. *et al. Energy & Environment Science*, 2009, 2, (2), 853–856.

When a layer of multi-walled carbon nanotubes was deposited on the surface of a poly(3-hexylthiophene) layer on a SnO_2-modified glass electrode, the maximum power output of a dye-sensitised photovoltaic solar cell increased by a factor of 1.35.

10/00821 ANN-based modelling and estimation of daily global solar radiation data: a case study

Benghanem, M. *et al. Energy Conversion and Management*, 2009, 50, (7), 1644–1655.

In this paper, an artificial neural network (ANN) models for estimating and modelling of daily global solar radiation have been developed. The data used in this work are the global irradiation H_G, diffuse irradiation H_D, air temperature T and relative humidity H_u. These data are available from 1998 to 2002 at the National Renewable Energy Laboratory (NREL) website. The authors have developed six ANN-models by using different combination as inputs: the air temperature, relative humidity, sunshine duration and the day of year. For each model, the output is the daily global solar radiation. Firstly, a set of 4 × 365 points (4 years) has been used for training each networks, while a set of 365 points (1 year) has been used for testing and validating the ANN-models. It was found that the model using sunshine duration and air temperature as inputs, gives good accurate results since the correlation coefficient is 97.65%. A comparative study between developed ANN-models and conventional regression models is presented in this study.

10/00822 CO_2 emissions mitigation potential of solar home systems under clean development mechanism in India

Purohit, P. *Energy*, 2009, 34, (8), 1014–1023.

The Indian government has taken several initiatives for promotion of solar energy systems in the country during the past two decades. A variety of policy measures have been adopted which include provision of financial and fiscal incentives to the potential users of solar energy systems however, only 0.4 million solar home systems (SHSs) have been installed so far that is far below their respective potential. One of the major barriers is the high costs of investments in these systems. The clean development mechanism (CDM) of the Kyoto Protocol provides industrialized (Annex-I) countries with an incentive to invest in emission reduction projects in developing (non-Annex-I) countries to achieve a reduction in carbon dioxide (CO_2) emissions at lowest cost that also promotes sustainable development in the host country. SHSs could be of interest under the CDM because they directly displace greenhouse gas (GHG) emissions while contributing to sustainable rural development, if developed correctly. In this study an attempt has been made to estimate the CO_2 mitigation potential of SHSs under CDM in India.

10/00823 Design and performance of a solar-powered heating and cooling system using silica gel/water adsorption chiller

Chang, W.-S. *et al. Applied Thermal Engineering*, 2009, 29, (10), 2100–2105.

In this paper, a solar-powered compound system for heating and cooling was designed and constructed in a golf course in Taiwan. An integrated, two-bed, closed-type adsorption chiller was developed in the Industrial Technology Research Institute in Taiwan. Plate fin and tube heat exchangers were adopted as an adsorber and evaporator/condenser. Some test runs have been conducted in the laboratory. Under the test conditions of 80 °C hot water, 30 °C cooling water, and

14 °C chilled water inlet temperatures, a cooling power of 9 kW and a COP (coefficient of performance for cooling) of 0.37 can be achieved. It has provided a SCP (specific cooling power) of about 72 W/(kg adsorbent). Some field tests have been performed from July to October 2006 for providing air-conditioning and hot water. The efficiency of the collector field lies in 18.5–32.4%, with an average value of 27.3%. The daily average COP of the adsorption chiller lies in 33.8–49.7%, with an average COP of 40.3% and an average cooling power of 7.79 kW. A typical daily operation shows that the efficiency of the solar heating system, the adsorption cooling and the entirely solar cooling system is 28.4%, 45.2%, and 12.8%, respectively.

10/00824 Effect of air gap on the performance of building-integrated photovoltaics

Gan, G. *Energy*, 2009, 34, (7), 913–921.

Ventilation of photovoltaic (PV) modules installed over or beside a building envelope can reduce the module temperature and increase the electrical conversion efficiency. A computational fluid dynamics (CFD) method has been used to assess the effect of the size of air gap between PV modules and the building envelope on the PV performance in terms of cell temperature for a range of roof pitches and panel lengths and to determine the minimum air gap that is required to minimize PV overheating. It has been found that the mean PV temperature and the maximum PV temperature associated with hot spots decrease with the increase in pitch angle and air gap. The mean PV temperature also decreases with increasing panel length for air gaps greater than or equal to 0.08 m whereas the maximum PV temperature generally increases with panel length. To reduce possible overheating of PV modules and hot spots near the top of modules requires a minimum air gap of 0.12–0.15 m for multiple module installation and 0.14–0.16 m for single module installation depending on roof pitches.

10/00825 Effect of different types of clouds on surface UV-B and total solar irradiance at southern mid-latitudes: CMF determinations at Córdoba, Argentina

López, M. L. *et al. Atmospheric Environment*, 2009, 43, (19), 3130–3136.

The effect of clouds on total and UV-B irradiance in Córdoba, Argentina, was studied employing the TUV 4.1 model and measurements obtained with YES UVB-1 and YES TSP-700 radiometers, and a spectral radiometer Ocean Optics USB-4000. The experimental measurements were selected from a 10-year dataset (1999–2008). Clouds were classified by direct observation as cirrus, cumulus, and stratocumulus. The broadband Cloud Modification Factors (CMFs) have been calculated in the range of the total and the UV-B radiation for these types of clouds. The relations between them were analysed for a significant number of days. The broadband CMF values range from around 0.1 up to 1.25, depending on the wavelength interval and on the cloud type. The $\mathrm{CMF}_{\mathrm{UVB}}$ versus $\mathrm{CMF}_{\mathrm{T}}$ plots for different clouds have shown good adjustments and significant differences, which allows the distinction between them. Stratocumulus clouds show large attenuations and a linear relation with larger slopes as the solar zenith angle (SZA) increases. For this type of clouds an average slope of (1.0 ± 0.2) was found. The relation between the CMF for cumulus clouds is linear with an average slope of (0.61 ± 0.01). No dependence with the SZA was observed. Cirrus clouds plots show an exponential behaviour with fit parameters equal to (0.48 ± 0.08) and (0.68 ± 0.15). However, when small SZA intervals are analysed a linear relation is found. When the relations between the CMF were similar (cumulus and cirrus), the spectral variation in the UV range (320–420 nm) of a modified CMF ($\mathrm{CMF}_{\mathrm{m}}$) was used to distinguish them. Hence, the spectral differences among the three types of clouds have been also analysed for several days and SZA. Here, it was found that the effect of cirrus is essentially wavelength independent while cumulus and stratocumulus clouds show exponential decay relations but with different ordinates. In the analysed relations the microphysical properties of the clouds seem to determine its behaviour while the optical thickness leads to the different degrees of attenuation. The results obtained in this work are in agreement with those found for other authors.

10/00826 Energy and exergy analysis of PV/T air collectors connected in series

Dubey, S. *et al. Energy and Buildings*, 2009, 41, (8), 863–870.

In this paper an attempt has been made to derive the analytical expressions for N hybrid photovoltaic/thermal (PV/T) air collectors connected in series. The performance of collectors is evaluated by considering the two different cases, namely, Case I (air collector is fully covered by PV module (glass to glass) and air flows above the absorber plate) and Case II (air collector is fully covered by PV module (glass to glass) and air flows below the absorber plate). This paper shows the detailed analysis of energy, exergy and electrical energy by varying the number of collectors and air velocity considering four weather conditions (a, b, c and d type) and five different cities (New Delhi, Bangalore, Mumbai, Srinagar, and Jodhpur) of India. It is found that the collectors fully covered by PV module and air flows below the absorber plate gives better results in terms of thermal energy, electrical energy and exergy gain. Physical implementation of BIPV system has also been evaluated. If this type of system is installed on roof of building or integrated with building envelope will simultaneously fulfil the electricity generation for lighting purpose and hot air can be used for space heating or drying.

10/00827 Estimating the manufacturing cost of purely organic solar cells

Kalowekamo, J. and Baker, E. *Solar Energy*, 2009, 83, (8), 1224–1231.

This study estimated the manufacturing cost of purely organic solar cells. A very large range was found since the technology is still very young. It was estimated that the manufacturing cost for purely organic solar cells will range between \$50 and \$140/m^2. Under the assumption of 5% efficiency, this leads to a module cost of between \$1.00 and \$2.83/W$_\mathrm{p}$. Under the assumption of a 5-year lifetime, this leads to a levelized cost of electricity (LEC) of between 49¢ and 85¢/kWh. In order to achieve a more competitive COE of about 7¢/kWh, efficiency would need to increase to 15% and lifetime to between 15–20 years.

10/00828 Evaluation of the aging behavior of ethylene copolymer films for solar applications under accelerated weathering conditions

Oreski, G. and Wallner, G. M. *Solar Energy*, 2009, 83, (7), 1040–1047.

Ethylene copolymers based on acrylic acids and acrylates are an interesting alternative to ethylene(vinylacetate) (EVA) for photovoltaic (PV) encapsulation. These materials provide similar or better mechanical and optical properties and a slightly better ageing behaviour, but without the formation of corrosive acetic acid during ageing, which is particularly of importance in PV applications. The focus of the research work was to evaluate and screen the ageing behaviour of ethylene copolymers containing different types of comonomers for solar applications. To investigate the intrinsic weathering behaviour of the materials, unstabilized films with comonomer contents around 10% were exposed to temperature, humidity and solar radiation. Special attention was given to the optical and mechanical properties. All investigated films showed high transparency in the solar range with hemispheric transmittance values above 91%. Regarding mechanical properties, the ethylene copolymer films exhibited a highly ductile behaviour and high flexibility. Similar degradation behaviour could be observed for all investigated films. Due to formation of chromophoric degradation products, yellowing could be observed and hemispheric transmittance values dropped slightly to values between 88.5 and 90.5%. The unstabilized films showed significant embrittlement due to weathering. After 750 h of weathering both strain-at-break and stress-at-break values of all ethylene copolymer films dropped significantly below 50% of the initial values.

10/00829 Fluid selection for a low-temperature solar organic Rankine cycle

Tchanche, B. F. *et al. Applied Thermal Engineering*, 2009, 29, (11–12), 2468–2476.

Theoretical performances as well as thermodynamic and environmental properties of few fluids have been comparatively assessed for use in low-temperature solar organic Rankine cycle systems. Efficiencies, volume flow rate, mass flow rate, pressure ratio, toxicity, flammability, ODP and GWP were used for comparison. Of 20 fluids investigated, R134a appears as the most suitable for small scale solar applications. R152a, R600a, R600 and R290 offer attractive performances but need safety precautions, owing to their flammability.

10/00830 Heat transfer and friction correlations for artificially roughened solar air heater duct with discrete W-shaped ribs

Kumar, A. *et al. Energy Conversion and Management*, 2009, 50, (8), 2106–2117.

An experimental investigation has been carried out to study the heat transfer and friction characteristics in solar air heater by using discrete W-shaped roughness on one broad wall of solar air heater with an aspect ratio of 8:1, the roughened wall being heated while the remaining three walls are insulated. The experiment encompassed Reynolds number (*Re*) range from 3000 to 15,000, relative roughness height (e/D_h) in the range of 0.0168–0.0338, relative roughness pitch (p/e) 10 and the angle of attack (α) in the range of 30–75°. The effect of parameters on the heat transfer and friction are compared with the result of smooth duct under similar flow conditions. Correlations for heat transfer and friction have been developed as a function of roughness and flow parameters.

10/00831 Indoor simulation and testing of photovoltaic thermal (PV/T) air collectors

Solanki, S. C. *et al. Applied Energy*, 2009, 86, (11), 2421–2428.

An indoor standard test procedure has been developed for thermal and electrical testing of PV/T collectors connected in series. For this, a PV/T solar air heater has been designed, fabricated and its performance over different operating parameters were studied. Based on the energy balance equations, in a steady state condition, a thermal model has been developed. Comparison between experimental and theoretical results were also been carried out. The thermal and electrical efficiency of the solar heater is 42% and 8.4%, respectively. This test procedure can be used by manufacturers for testing of different types of PV modules in order to optimize its products.

10/00832 Nanochemistry aspects of titania in dye-sensitized solar cells

Pagliaro, M. *et al. Energy & Environment Science*, 2009, 2, (2), 838–844.
This study analyses the main nanochemistry factors affecting photovoltaic performance in TiO_2 employed as wide bandgap semiconductor in dye-sensitized solar cells. What is the best morphology of the oxide? Which processes yield the required structures? Finally, putting the discussion in the context of the rapid evolution of photovoltaic technologies, the authors argue that new titania nanostructures will form the basic component of second-generation solar modules based on dye solar cells.

10/00833 Numerical 3-D heat flux simulations on flat plate solar collectors

Villar, N. M. *et al. Solar Energy*, 2009, 83, (7), 1086–1092.
A transient 3-D mathematical model for solar flat plate collectors has been developed. The model is based on setting mass and energy balances on finite volumes. The model allows the comparison of different configurations: parallel tubes collectors (PTC), serpentine tube collectors (STC), two parallel plate collectors (TPPC), and other non-usual possibilities like the use of absorbent fluids with semitransparent or transparent plates. Transparent honeycomb insulation between plate and cover can also be modelled. The effect of temperature on the thermal properties of the materials has also been considered. The model has been validated experimentally with a commercial PTC. The model is a useful tool to improve the design of plate solar collectors and to compare different configurations. In order to show the capabilities of the model, the performance of a PTC collector with non-uniformity flow is analysed and compared with experimental data from literature with good agreement.

10/00834 Optical properties of liquids for direct absorption solar thermal energy systems

Otanicar, T. P. *et al. Solar Energy*, 2009, 83, (7), 969–997.
A method for experimentally determining the extinction index of four liquids (water, ethylene glycol, propylene glycol, and Therminol VP-1) commonly used in solar thermal energy applications was developed. In addition to the extinction index, the refractive indices available within the literature for these four fluids was reported. The final value reported is the solar-weighted absorption coefficient for the fluids demonstrating each fluid's baseline capacity for absorbing solar energy. Water is shown to be the best absorber of solar energy of the four fluids, but it is still a weak absorber, only absorbing 13% of the energy. These values represent the baseline potential for a fluid to be utilized in a direct absorption solar thermal collector.

10/00835 Performance analysis of tracked panel according to predicted global radiation

Chang, T. P. *Energy Conversion and Management*, 2009, 50, (8), 2029–2034.
In this paper, the performance of a south-facing single-axis tracked panel was analysed according to global radiation predicted by empirical model. Mathematic expressions appropriate for single-axis tracking system were derived to calculate the radiation on it. Instantaneous increments of solar energy collected by the tracked panel relative to fixed panel are illustrated. The validity of the empirical model to Taiwan area will also be examined with the actual irradiation data observed in Taipei. The results are summarized as follows: the gains made by the tracked panel relative to a fixed panel are between 20.0% and 33.9% for four specified days of year, between 20.9% and 33.2% for the four seasons and 27.6% over the entire year. For latitudes below 65°, the yearly optimal tilt angle of a fixed panel is close to 0.8 times latitude, the irradiation ratio of the tracked panel to the fixed panel is about 1.3, which are smaller than the corresponding values calculated from extraterrestrial radiation, suggesting us that the installation angle should be adjusted toward a flatter angle and that the gain of the tracked panel will reduce while it works in cloudy climate or in air pollution environment. Although the captured radiation increases with the maximal rotation angle of panel, but the benefit on the global radiation case is still not so good as that on extraterrestrial radiation case. The irradiation data observed is much less than the data predicted by the empirical model, however the trend of fitting curve to the observed data is somewhat in agreement with that to the predicted one; the yearly gain is 14.3% when a tracked panel is employed throughout the year.

10/00836 Public demonstration projects and field trials: accelerating commercialisation of sustainable technology in solar photovoltaics

Brown, J. and Hendry, C. *Energy Policy*, 2009, 37, (7), 2560–2573.
The paper considers the role of government-funded demonstration projects and field trials (DTs) in accelerating the commercialization of new energy technologies that meet a public good but do not have immediate market appeal. Drawing on an original database of DTs in the EU, Japan and USA from 1973 to 2004, this study reviews the history of DTs in photovoltaic technology for electricity generation, and its subsequent take up as a commercial energy source. The authors find that DTs aimed purely at discovering suitable market opportunities are less successful in achieving diffusion than projects that target a particular application and concentrate resources on it. The former nevertheless have a vital role to play in the learning process, while a targeted focus is often dependent on national industrial and institutional factors.

10/00837 Robust maximum power point tracking method for photovoltaic cells: a sliding mode control approach

Chu, C.-C. and Chen, C.-L. *Solar Energy*, 2009, 83, (8), 1370–1378.
Due to non-linear I-V characteristics of photovoltaic cells, an maximum power point tracking algorithm is adopted to maximize the output power. In this paper, an approach for peak power tracking using the sliding mode control is proposed. The proposed controller is robust to environment changes and load variations. The stability and robustness of the controller are addressed. The performance of the controller is verified through simulations and experiments. It demonstrated that the proposed approach can be implemented effectively and economically.

10/00838 Solar collector overheating protection

Slaman, M. and Griessen, R. *Solar Energy*, 2009, 83, (7), 982–987.
Prismatic structures in a thermal solar collector are used as overheating protection. Such structures reflect incoming light efficiently back whenever less thermal power is extracted from the solar collector. Maximum thermal power is generated when the prismatic structure is surrounded by a switching fluid with an index of refraction comparable to that of the prismatic structure. Thermal heat can be harvested via extra fluid channels in the solar absorber or directly via the switching fluid near the prisms. The light reducing effect of prismatic structures is demonstrated for a typical day and a season cycle of the Earth around the Sun. The switchability and the light reducing effect are also demonstrated in a prototype solar collector.

10/00839 Two-stage direct expansion solar-assisted heat pump for high temperature applications

Chaturvedi, S. K. *et al. Applied Thermal Engineering*, 2009, 29, (10), 2093–2099.
Direct expansion solar-assisted heat pump (DX-SAHP) systems have been proposed as viable alternatives to conventional solar-assisted heat pump systems. This study proposes the use of two-stage DX-SAHP systems for high temperature applications in the range of 60–90 °C. The study investigates the capability of these systems of meeting loads with high temperature requirements. The thermal performance of the systems is analysed for refrigerant R-134a, using a one-cover solar collector. Comparisons between the two-stage DX-SAHP and the single-stage DX-SAHP systems are performed and presented. A graphical procedure is illustrated and used for sizing the solar collector area and the heat pump compressor displacement capacity for the two DX-SAHP systems.

Wind energy

10/00840 A fuzzy logic supervisor for active and reactive power control of a variable speed wind energy conversion system associated to a flywheel storage system

Jerbi, L. *et al. Electric Power Systems Research*, 2009, 79, (6), 919–925.
This study proposes a wind energy conversion system (WECS) at variable speed using a doubly fed induction generator (DFIG) controlled on the rotor side through converters. A flywheel energy storage system (FESS) is connected to the studied wind generator at the DC bus in order to evaluate its capacity to participate to the ancillary services. The authors study the improvement of the active and reactive power quality produced by the wind generator and its effect on the load voltage regulation connected to the wind generator. For that, a fuzzy logic supervisor is established to control the FESS operation and the DC bus voltage in order to smooth the active power fluctuations due to the random wind speed variations. A control law is also described to smooth the reactive power at the connection node to the grid.

10/00841 A new method to estimate Weibull parameters for wind energy applications

Akdağ, S. A. and Dinler, A. *Energy Conversion and Management*, 2009, 50, (7), 1761–1766.

In recent years, Weibull distribution has been commonly used, accepted and recommended distribution in literature to express the wind speed frequency distribution. In this study, a new method is developed to estimate Weibull distribution parameters for wind energy applications. This new method is called power density method. In literature most frequently used methods, that are graphic, maximum likelihood and moment methods, are revisited and a comparison between these methods and power density method is carried out. Suitability of these methods is judged based on different goodness of fit tests for different geographical locations. Also to demonstrate the accuracy of power density method, comparisons are carried out based on power density and mean wind estimation results of previous studies. Results of this study indicate that power density method is an adequate method to estimate Weibull parameters and it might have better suitability than other methods. Some superiority of the new power density method are that, it has simple formulation, it does not require binning and solving linear least square problem or iterative procedure. If power density and mean wind speed are available it is very simple to estimate Weibull parameters.

10/00842 Capacity factor of wind power realized values vs. estimates

Boccard, N. *Energy Policy*, 2009, 37, (7), 2679–2688.

For two decades now, the capacity factor of wind power measuring the average energy delivered has been assumed in the 30–35% range of the name plate capacity. Yet, the mean realized value for Europe over the last five years is below 21%; accordingly private cost is two-thirds higher and the reduction of carbon emissions is 40% less than previously expected. The authors document this discrepancy and offer rationalizations that emphasize the long-term variations of wind speeds, the behaviour of the wind power industry, political interference and the mode of finance. The authors conclude with the consequences of the capacity factor miscalculation and some policy recommendations.

10/00843 Direct employment in the wind energy sector: an EU study

Blanco, M. I. and Rodrigues, G. *Energy Policy*, 2009, 37, (8), 2847–2857.

Wind energy is often said to have positive effects on employment, but few studies have systematically dealt with this matter. This article presents estimates of direct wind energy employment in all EU countries, gathered for the first time. By using a thematic survey, the authors have been able to analyse aspects such as gender distribution, company profiles and the shortage of skilled workers reported by wind energy companies. The outcomes show that wind energy deployment creates a significant number of jobs (over 104,000 in 2008), and does so at a time when other energy sectors are shrinking. There is a clear relationship between MW installed and number of jobs, but the use of a single EU job/MW ratio is not feasible, due to differences in the export/import capacity. Wind turbine manufacturers – including major sub-components – are responsible for the lion's share of the jobs, and there is a marked prevalence of males in the workforce. The scarcity of specialist roles – project managers, engineers and O&M technicians – is not likely to be solved unless a series of educational, mobility and dissemination measures are put into practice.

10/00844 Electricity generation scheduling with large-scale wind farms using particle swarm optimization

Siahkali, H. and Vakilian, M. *Electric Power Systems Research*, 2009, 79, (5), 826–836.

Large-scale integration of wind power in the electricity system presents some planning and operational difficulties, which are mainly due to the intermittent and difficult nature of wind prediction process. Therefore it is considered as an unreliable energy source. This paper presents a new approach for solving the generation scheduling problem. It will consider the reserve requirement, load balance and wind power availability constraints. The particle swarm optimization (PSO) method is suggested to deal with the equality and inequality constraints in the generation scheduling problem. The proposed PSO is applied to a 12-unit test system (including 10 conventional thermal generating units and 2 wind farms) to determine the acceleration constants of proposed PSO and the global variant-based passive congregation PSO (GPAC). Employing these constants which correspond to the best total cost function, the performance of proposed PSO and GPAC are determined, through comparison of their results for three specific test systems. Evaluation of the solution for these test systems demonstrates that near optimal schedules are obtained with application of proposed PSO.

10/00845 Evaluating operational risk in a power system with a large amount of wind power

Gouveia, E. M. and Matos, M. A. *Electric Power Systems Research*, 2009, 79, (5), 734–739.

Reserve definition is a compromise between economic issues (additional capacity costs) and reliability (risk of loss of load due to outages of the generators), generally approached by deterministic criteria (e.g. the percentage rule defined by UCTE in Europe) and probabilistic methods like PJM (Pennsylvania–New Jersey, Maryland) and its enhancements, based on the concept of risk. With wind power generation increasing in power systems worldwide, these operational issues gain a renewed interest due to the volatile nature of this kind of energy. The aim of this paper is therefore to address this issue from a risk evaluation point of view, showing that it is possible to extend classical probabilistic methods to this new situation, by introducing a detailed Markov model of wind parks that accounts both for machine failures and different wind power levels. This evaluation, where wind generation fluctuation and uncertainty is included, can be helpful for transmission system operators (TSO), when defining the reserve requirements for the next hours. In fact, the results obtained for the risk can be used by TSO to check if the reserve levels that results from traditional deterministic rules are acceptable or need to be increased.

10/00846 Exergy analysis in a wind speed prognostic model as a wind farm sitting [siting] selection tool: a case study in Southern Greece

Xydis, G. *et al. Applied Energy*, 2009, 86, (11), 2411–2420.

In the present paper, the wind potential of Central Peloponnese in Greece has been studied and the exergy analysis methodology was implemented as a wind-farm siting selection tool. The wind speed of the chosen regions of Central Peloponnese was studied and correlated based on the measurements of three specific sites in the wider area using a software based prognostic model using intercomparisons of cross-predictions among these sites. The exergy analysis implemented in this innovative wind speed forecasting model is used to identify the actual use of energy from the existing available energy and to evaluate the proposed sites appropriate for wind farm development ending up to an accurate wind map of the area.

10/00847 Onshore wind power development in China: challenges behind a successful story

Han, J. *et al. Energy Policy*, 2009, 37, (8), 2941–2951.

Wind energy utilization, especially onshore grid-connected wind power generation, has a history of 30 years in China. With the increasing attention to renewable energy development in recent years, wind energy has become the focus of academic research and policy-making. While the potential and advantages of wind energy are widely recognized, many questions regarding the effectiveness of policies and performances of current practices remain unanswered. This paper takes Inner Mongolia, the province that has the most abundant wind energy resources in China, as a case to assess the performance of Chinese onshore wind power projects, focusing on the institutional setting, economic and technological performance, as well as environmental and social impacts. Results show that China is experiencing a rapid growth in wind power generation, which brings China great environmental, energy security and social benefits. However, for a full development of wind energy in China, a number of barriers need to be removed: high generation cost, low on-grid price, and stagnating development of domestic manufacture. These findings lead to three policy recommendations.

10/00848 Overcoming barriers to wind project finance in Australia

Kann, S. *Energy Policy*, 2009, 37, (8), 3139–3148.

The wind power industry in Australia is expected to grow rapidly over the next decade, primarily due to a forthcoming expanded national renewable energy target (RET) which will mandate that renewable sources provide approximately 20% of Australia's electricity production by 2020. However, development of new wind generation in Australia has stalled as a result of several barriers to project finance, the mechanism through which most wind farms have been developed historically. This paper provides an overview of wind power financing in Australia in light of recent political and financial trends. Drawing upon existing literature and a series of stakeholder interviews, it identifies three primary barriers to project finance: regulatory risk surrounding legislation of the RET, semi-privatization of electricity retailers in New South Wales, and limited capital availability resulting from the recent global credit crisis. The paper concludes that the confluence of these barriers limits the availability of long-term contracts that provide revenue certainty for pre-construction wind projects, while simultaneously making these contracts a necessity in order to obtain project finance. In an attempt to mitigate these effects, this paper identifies four alternative development strategies that can be pursued.

10/00849 Wind energy (30%) in the Spanish power mix – technically feasible and economically reasonable

Zubi, G. *et al. Energy Policy*, 2009, 37, (8), 3221–3226.

The installed wind power capacity in Spain has grown strongly in recent years. In 2007, wind parks supplied already 10% of the 260 TWh generated electricity. Along that year the installed wind capacity grew by 33.2%, from 11.63 GW in January to 15.5 GW in December. Wind is nowadays the primer renewable power source in Spain, while the public perception of renewables in general is very positive. The issue of the integration of wind power as a fluctuating source into the power grid is gaining priority. This study shows that a relatively high share of wind power in Spain can be assimilated by the grid despite the fluctuating character of this energy and despite the fluctuating demand, and without affecting negatively the economy of the power supply systems and of wind farms.

Others, including economics

10/00850 Automatic generation control of TCPS based hydrothermal system under open market scenario: a fuzzy logic approach

Srinivasa Rao, C. *et al. International Journal of Electrical Power & Energy Systems*, 2009, 31, (7–8), 315–322.

This paper presents the analysis of automatic generation control (AGC) of a two-area interconnected thyristor controlled phase shifter (TCPS) based hydrothermal system in the continuous mode using fuzzy logic controller under open market scenario. Open transmission access and the evolving of more socialized companies for generation, transmission and distribution affects the formulation of AGC problem. So the traditional AGC two-area system is modified to take into account the effect of bilateral contracts on the dynamics. It is possible to stabilize the system frequency and tie-power oscillations by controlling the phase angle of TCPS which is expected to provide a new ancillary service for the future power systems. A control strategy using TCPS is proposed to provide active control of system frequency. Further dynamic responses for small perturbation considering fuzzy logic controller and PI controller (dual mode controller) have been observed and the superior performance of fuzzy logic controller has been reported analytically and also through simulation.

10/00851 An improved model and the thermodynamic calculation method for tailrace tunnel ventilating system in hydropower station

Yu, Y. *et al. Energy Conversion and Management*, 2009, 50, (8), 2060–2066.

Tailrace tunnel ventilating can be used as a highly efficient and energy saving air conditioning for factory buildings in hydropower station. This paper describes an improved model of heat and moisture transfer for tailrace tunnel ventilating system with the assumption of thermal insulated for the tunnel wall and with the same temperature at any cross section as the wet bulb temperature of that air, and the improved model has been validated against the field test from Yingxiuwan hydropower station and compared with the reference simplified model, the results show that the improved model has a good agreement with the field test data and a better precision than the reference simplified model for the performance prediction of heat and moisture transfer of tailrace tunnel ventilating, especially for the short tunnel system. Moreover, the thermodynamic calculation method of heat and moisture transfer is presented, and the method is intended for use in annual performances prediction or design tools for tailrace tunnel ventilating system in hydropower station.

10/00852 Analysis of a small wind-hydrogen stand-alone hybrid energy system

Khan, M. J. and Iqbal, M. T. *Applied Energy*, 2009, 86, (11), 2429–2442.

A detailed modelling, simulation, and analysis of an isolated wind-hydrogen hybrid energy system is presented. Dynamic non-linear models of all the major subsystems are developed based on sets of empirical and physical relationships. The performance of the integrated hybrid energy system is then analysed through digital simulation. Design of dynamic controllers and supervisory control schemes are also presented. Expected behaviours during sudden load variation, wind speed change and hydrogen pressure drop are observed under both stochastic and step-variation conditions. MATLAB-Simulink$^{\mathrm{TM}}$ is employed for dynamic system modelling. This exercise, in essence, outlines a process of wind-hydrogen off-grid system control synthesis and performance evaluation. Finally, results of the analysis are summarized, limitations of the simulation study are identified, and scope for future work is indicated.

10/00853 Are forestation, bio-char and landfilled biomass adequate offsets for the climate effects of burning fossil fuels?

Reijnders, L. *Energy Policy*, 2009, 37, (8), 2839–2841.

Forestation and landfilling purpose-grown biomass are not adequate offsets for the CO_2 emission from burning fossil fuels. Their permanence is insufficiently guaranteed and landfilling purpose-grown biomass may even be counterproductive. As to permanence, bio-char may do better than forests or landfilled biomass, but there are major uncertainties about net greenhouse gas emissions linked to the bio-char life cycle, which necessitate suspension of judgement about the adequacy of bio-char addition to soils as an offset for CO_2 emissions from burning fossil fuels.

10/00854 Controlled electrochemical dissolution of hydrothermal and sedimentary pyrite

Liu, R. *et al. Applied Geochemistry*, 2009, 24, (5), 836–842.

Electrochemically controlled pyrite dissolution was performed with three pyrite materials from different geological origins under mixed potential and high overpotential conditions. Both solid electrodes and C paste electrodes of powdered pyrite were used. The rate of pyrite dissolution increased with applied positive potential and was strongly affected by temperature. Current density measurements over the applied potential range successfully described the rate of pyrite dissolution of each pyrite electrode. Controlled dissolution performed under mixed potential conditions on the solid electrodes successfully reflected the same pyrite reactivity and dissolution rate order as in batch reactor dissolution studies with the same pyrite materials. Therefore, the relative reactivity of different pyrite materials can be determined through current density measurements on their solid electrodes under mixed potential conditions. This technique could be a useful tool to compare rapidly the relative reactivity for different pyrite materials. In contrast, electrochemically controlled dissolution studies with C paste electrodes constructed with fine-grained pyrite and paraffin/graphite mixture did not result in accurate ranking of pyrite samples by dissolution rate.

10/00855 Cost effective process for high-efficiency solar cells

Lee, S. H. *Solar Energy*, 2009, 83, (8), 1285–1289.

A new method for patterning the rear passivation layers of high-efficiency solar cells with a mechanical scriber has been developed and successfully adapted to fabricate high-efficiency passivated emitter and rear cell (PERC). Three types of the rear contact patterns: dot patterns with a photolithography process, line and dashed line patterns with a mechanical scriber process have been processed in order to optimize the rear contact structure. An efficiency of 19.42% has been achieved on the mechanical-scribed (MS)-PERC solar cell on 0.5 Ω cm p-type FZ-Si wafer and is comparable to that of conventional PERC solar cells fabricated by using photolithography process. The mechanical scriber process shows great potential for commercial applications by achieving high efficiency above 20% and by significantly reducing the fabrication costs without an expensive photolithography process. Low-cost Ni/Cu metal contact has been formed by using a low-cost electroless and electroplating. Nickel silicide formation at the interface enhances stability and reduces the contact resistance resulting in an energy conversion efficiency of 20.2% on 0.5 Ω cm FZ wafer.

10/00856 Energy and cost studies of semi-transparent photovoltaic skylight

Li, D. H. W. *et al. Energy Conversion and Management*, 2009, 50, (8), 1981–1990.

Sustainability is the trend of the modern building designs, in which solar energy conversion systems and daylighting schemes are widely considered as the important building energy strategies to reduce the peak cooling and electrical demands, generate clean energy and save the building electricity expenditures. A semi-transparent photovoltaic (PV) is a renewable energy product producing electricity via solar cells and allowing natural light entering into the interior spaces for daylighting designs. The PV modules are effective in reducing the cooling demand, especially for the skylight atrium that often receives large solar heat gains. This paper studies the thermal and visual properties, energy performance, environmental and financial issues of such semi-transparent PV skylights. Field measurements including solar irradiance, daylight illuminance and electricity generated were carried out. Case studies based on a circulating atrium were conducted to evaluate the energy use, cooling requirements and monetary implications when the PV skylights together with the daylight-linked lighting controls were applied. The results indicated that such an integrated system could save the overall electricity expenditures and benefit to the environmental and financial aspects.

10/00857 Growing season methane budget of an Inner Mongolian steppe

Liu, C. *et al. Atmospheric Environment*, 2009, 43, (19), 3086–3095.

This study presents a methane (CH_4) budget for the area of the Baiyinxile livestock farm, which comprises approximately one-third of the Xilin river catchment in central Inner Mongolia, China. The budget calculations comprise the contributions of natural sources and sinks as well as sources related to the main land-use in this region (non-nomadic pastoralism) during the growing season (May–September). The following areas were identified as important CH_4 sources floodplains (mean $1.55 \pm 0.97\,\mathrm{mg\,CH_4\text{–}C\,m^{-2}\,h^{-1}}$) and domestic ruminants, which are mainly sheep in this area. Within the floodplain significant differences between investigated positions were detected, whereby only positions close-by the river or bayous emitted large amounts of CH_4 (mean up to $6.21 \pm 1.83\,\mathrm{mg\,CH_4\text{–}C\,m^{-2}\,h^{-1}}$). Further CH_4 sources were sheepfolds ($0.08\text{–}0.91\,\mathrm{mg\,CH_4\text{–}C\,m^{-2}\,h^{-1}}$) and pasture faeces ($1.34 \pm 0.22\,\mathrm{mg\,CH_4\text{–}C\,g^{-1}}$ faeces dry weight), but they did not play a significant role for the CH_4 budget. In contrast, dung heaps were not a net source of CH_4 (0.0 ± 0.2 for an old and $0.0 \pm 0.3\,\mathrm{\mu g\,CH_4\text{–}C\,kg^{-1}\,h^{-1}}$ for a new dung heap). Trace gas measurements along two landscape transects (volcano, hill slope) revealed expectedly a mean CH_4 uptake (volcano: 76.5 ± 4.3; hill: $28.3 \pm 5.3\,\mathrm{\mu g\,CH_4\text{–}C\,m^{-2}\,h^{-1}}$), which is typical for the aerobic soils in this and other steppe ecosystems. The observed fluxes were rarely influenced by topography. The CH_4 emissions from the floodplain and the sheep were not compensated by the CH_4 oxidation of aerobic steppe soils and thus, this managed semi-arid grassland did not serve as a terrestrial sink, but as a source for this globally important greenhouse gas. The source strength amounted to $1.5\text{–}3.6\,\mathrm{kg\,CH_4\text{–}C\,ha^{-1}}$ during the growing season, corresponding to $3.5\text{–}8.7\,\mathrm{kg\,C\,ha^{-1}\,yr^{-1}}$.

10/00858 Integrating private transport into renewable energy policy: the strategy of creating intelligent recharging grids for electric vehicles

Andersen, P. H. *et al. Energy Policy*, 2009, 37, (7), 2481–2486.

A new business model for accelerating the introduction of electric vehicles into private transport systems involves the provision by an electric recharge grid operator (ERGO) of an intelligent rechargeable network in advance of the vehicles themselves. The ERGO business model creates a market for co-ordinated production and consumption of renewable energy. The innovative contribution of the model rests in its ability to combine two problems and thereby solve them in a fresh way. One problem derives from utilizing power grids with a substantial increase in renewable electric energy production (as witnessed in the Danish case with wind energy) and managing the resulting fluctuating supply efficiently. The other problem concerns finding ways to reduce CO_2 emissions in the transport sector. The ERGO business model effectively solves both problems, by transforming EVs into distributed storage devices for electricity, thus enabling a fresh approach to evening out of fluctuating and unpredictable energy sources, while drastically reducing greenhouse gas emissions. This integrated solution carries many other associated benefits, amongst which are the possibility of introducing vehicle-to-grid (V2G) distributed power generation; introducing IT intelligence to the grid, and creating virtual power plants from distributed sources; and providing new applications for carbon credits in the decarbonization of the economy. The countries and regions that have signed on to this model and are working to introduce it in 2009–2011 include Israel, Denmark, Australia, and in the USA, the Bay Area cities and the state of Hawaii.

10/00859 Islanding protection of active distribution networks with renewable distributed generators: a comprehensive survey

Chowdhury, S. P. *et al. Electric Power Systems Research*, 2009, 79, (6), 984–992.

Anti-islanding protection schemes currently enforce the renewable distributed generators (RDGs) to disconnect immediately and stop generation for grid faults through loss of grid (LOG) protection system. This greatly reduces the benefits of RDG deployment. For preventing disconnection of RDGs during LOG, several islanding operation, control and protection schemes are being developed. Their main objectives are to detect LOG and disconnect the RDGs from the utility. This allows the RDGs to operate as power islands suitable for maintaining uninterruptible power supply to critical loads. A major challenge for the islanding operation and control schemes is the protection coordination of distribution systems with bi-directional flows of fault current. This is unlike the conventional overcurrent protection for radial systems with unidirectional flow of fault current. This paper presents a comprehensive survey of various islanding protection schemes that are being developed, tested and validated through extensive research activities across the globe. The present trends of research in islanding operation of RDGs are also detailed in this paper.

10/00860 Multiobjective electric distribution system expansion planning using hybrid energy hub concept

Nazar, M. S. and Haghifam, M. R. *Electric Power Systems Research*, 2009, 79, (6), 899–911.

This paper presents a novel approach for optimal electric distribution system expansion planning (OEDSEP) using a hybrid energy hub concept. The proposed method uses an energy hub model to explore the impacts of energy carrier systems on OEDSEP procedure. This algorithm decomposes the OEDSEP problem into three subproblems to achieve an optimal expansion planning of a system in which the investment and operational costs are minimized, while the reliability of the system is maximized. The algorithm was successfully tested in the present research for an urban distribution system.

10/00861 Potential contribution of biomass to the sustainable energy development

Demirbas, M. F. *et al. Energy Conversion and Management*, 2009, 50, (7), 1746–1760.

Biomass is considered the renewable energy source with the highest potential to contribute to the energy needs of modern society for both the industrialized and developing countries worldwide. The most important biomass energy sources are wood and wood wastes, agricultural crops and their waste byproducts, municipal solid waste, animal wastes, waste from food processing, and aquatic plants and algae. Biomass is one potential source of renewable energy and the conversion of plant material into a suitable form of energy, usually electricity or as a fuel for an internal combustion engine, can be achieved using a number of different routes, each with specific pros and cons. Currently, much research has been focused on sustainable and environmental friendly energy from biomass to replace conventional fossil fuels. The main objective of the present study is to investigate global potential and use of biomass energy and its contribution to the sustainable energy development by presenting its historical development.

10/00862 Preliminary study of long-term wind characteristics of the Mexican Yucatán Peninsula

Soler-Bientz, R. *et al. Energy Conversion and Management*, 2009, 50, (7), 1773–1780.

Mexico's Yucatán Peninsula is one of the most promising areas for wind energy development within the Latin American region but no comprehensive assessment of wind resource has been previously published. This research presents a preliminary analysis of the meteorological parameters relevant to the wind resource in order to find patterns in their long-term behaviour and to establish a foundation for subsequent research into the wind power potential of the Yucatán Peninsula. Three meteorological stations with data measured for a period between 10 and 20 years were used in this study. The monthly trends of ambient temperature, atmospheric pressure and wind speed data were identified and are discussed. The directional behaviour of the winds, their frequency distributions and the related Weibull parameters are presented. Wind power densities for the study sites have been estimated and have been shown to be relatively low (wind power class 1), though a larger number of suitable sites needs to be studied before a definitive resource evaluation can be reported.

10/00863 Production and trading of biomass for energy – an overview of the global status

Heinimö, J. and Junginger, M. *Biomass and Bioenergy*, 2009, 33, (9), 1310–1320.

The markets for industrially used biomass for energy purposes are developing rapidly toward being international commodity markets. Determining international traded biomass volumes for energy purposes is difficult, for several reasons, such as challenges regarding the compilation of statistics on the topic. While for some markets (pellets and ethanol) separate overviews exist, no comprehensive statistics and summaries aggregating separate biomass streams are available. The aim of this paper is to summarize trade volumes for various biomasses used for energy and to review the challenges related to measurement of internationally traded volumes of biofuels. International trade of solid and liquid biofuels was estimated to be about 0.9 EJ for 2006. Indirect trade of biofuels thorough trading of industrial roundwood and material byproducts comprises the largest proportion of trading, having a share of about 0.6 EJ. The remaining amount consisted of products that are traded directly for energy purposes, with ethanol, wood pellets, and palm oil being the most important commodities. In 2004–2006, the direct trade of biofuels increased 60%, whereas indirect trade has been almost constant. When compared to current global energy use of biomass (about $50\,\mathrm{EJ\,yr^{-1}}$) and to the long-term theoretical trading potential between the major regions of the world ($80\text{–}150\,\mathrm{EJ\,yr^{-1}}$), the development of international trade of biomass for energy purposes is in its initial stage, but it is expected to continue to grow rapidly.

10/00864 Renewable energy in India: historical developments and prospects

Bhattacharya, S. C. and Jana, C. *Energy*, 2009, 34, (8), 981–991.

Promoting renewable energy in India has assumed great importance in recent years in view of high growth rate of energy consumption, high share of coal in domestic energy demand, heavy dependence on imports for meeting demands for petroleum fuels and volatility of world oil market. A number of renewable energy technologies (RETs) are now well established in the country. The technology that has achieved the most dramatic growth rate and success is wind energy; India ranks fourth in the world in terms of total installed capacity. India hosts the world's largest small gasifier programme and second largest biogas programme. After many years of slow growth, demand for solar water heaters appears to be gaining momentum. Small hydro has been growing in India at a slow but steady pace. Installation of some of the technologies appears to have slowed down in recent years; these include improved cooking stoves and solar photovoltaic systems. In spite of many successes, the overall growth of renewable energy in India has remained rather slow. A number of factors are likely to boost the future prospects of renewable energy in the country; these include global pressure and voluntary targets for greenhouse gas emission reduction, a possible future oil crisis, intensification of rural electrification program, and import of hydropower from neighbouring countries.

10/00865 Renewable energy in India: status and potential

Pillai, I. R. and Banerjee, R. *Energy*, 2009, 34, (8), 970–980.

A majority of the Indian population does not have access to convenient energy services (LPG, electricity). Though India has made significant progress in renewable energy, the share of modern renewables in the energy mix is marginal. This paper reviews the status and potential of different renewables (except biomass) in India. This paper documents the trends in the growth of renewables in India and establishes diffusion model as a basis for setting targets. The diffusion model is fitted tot the past trends for wind, small hydro and solar water heating and is used to establish future targets. The economic viability and green house gas (GHG) saving potential is estimated for each option. Several renewables have high growth rates, for example wind, Photovoltaic (PV) module manufacture and solar water heaters. New technologies like tidal, OTEC, solar thermal power plants and geothermal power plants are at the demonstration stage and future dissemination will depend on the experience of these projects.

10/00866 Renewable energy technology portfolio planning with scenario analysis: a case study for Taiwan

Chen, T.-Y. *et al. Energy Policy*, 2009, 37, (8), 2900–2906.

This paper presents the results of a case study of applying a systematic and proven process of technology portfolio planning with the use of scenario analysis to renewable energy developments in Taiwan. The planning process starts with decision values of technology development based on a survey of society leaders. It then generates, based on expert opinions and literature search, a set of major technology alternatives, which in this study include: wind energy, photovoltaic, bio-energy, solar thermal power, ocean energy, and geothermal energy. Through a committee of technical experts with diversified professional backgrounds, the process in this study next constructs three scenarios ('Season in the Sun', 'More Desire than Energy', and 'Castle in the Air') to encompass future uncertainties in the relationships between the technology alternatives and the decision values. Finally, through a second committee of professionals, the process assesses the importance and risks of these alternative technologies and develops a general strategic plan for the renewable energy technology portfolio that is responsive and robust for the future scenarios. The most important contributions of this paper are the clear description of the systematic process of technology portfolio planning and scenario analysis, the detailed demonstration of their application through a case study on the renewable energy development in Taiwan, and the valuable results and insights gained from the application.

10/00867 State renewable energy electricity policies: an empirical evaluation of effectiveness

Carley, S. *Energy Policy*, 2009, 37, (8), 3071–3081.

Over the past decade, state governments have emerged as US energy policy leaders. Across the country, states are adopting policy instruments aimed at carbon mitigation and renewable energy deployment. One of the most prevalent and innovative policy instruments is a renewable portfolio standard (RPS), which seeks to increase the share of renewable energy electrification in the electricity market. This analysis evaluates the effectiveness of state energy programs with an empirical investigation of the linkage between state RPS policy implementation and the percentage of renewable energy electricity generation across states. The authors use a variant of a standard fixed effects model, referred to as a fixed effects vector decomposition, with state-level data from 1998 to 2006. Results indicate that RPS implementation is not a significant predictor of the percentage of renewable energy generation out of the total generation mix, yet for each additional year that a state has an RPS policy, they are found to increase the total amount of renewable energy generation. These findings reveal a potentially significant shortcoming of RPS policies. Political institutions, natural resource endowments, deregulation, gross state product per capita, electricity use per person, electricity price, and the presence of regional RPS policies are also found to be significantly related to renewable energy deployment.

10/00868 Techno-economic analysis of a biodiesel production process from vegetable oils

Apostolakou, A. A. *et al. Fuel Processing Technology*, 2009, 90, (7–8), 1023–1031.

Biodiesel, which is defined as the monoalkyl esters of long chain fatty acids derived from a renewable lipid feedstock, has received considerable attention worldwide as a medium-term alternative to diesel fuel obtained from petroleum. Biodiesel can be produced by the transesterification of vegetable oils or animal fats using short-chain alcohols in the presence of a suitable catalyst and glycerol is the only byproduct obtained in significant quantities. In this work a techno-economic analysis of a process that produces biodiesel from vegetable oils is presented with the aim to investigate the dependence of the critical profitability indicators on the production capacity.

10/00869 The diverging paths of German and United States policies for renewable energy: sources of difference

Laird, F. N. and Stefes, C. *Energy Policy*, 2009, 37, (7), 2619–2629.

The USA and Germany started out with very similar policies for renewable energy after the energy crisis of the 1970s. By the year 2000 they were on very different policy paths and, as a result, the German renewable energy industry has moved well ahead of that in the USA, both in terms of installed capacity in the country and in terms of creating a highly successful export market. This study rejects some of the conventional explanations for this difference. Instead, these differences arise from the intersection of contingent historical events with the distinctive institutional and social structures that affect policy making in each country. This analysis of the historical path-dependent dynamics of each country suggests that those who wish to further renewable energy policy in the USA need to take into account these institutional and social factors so that they will better be able to exploit the next set of favourable historical circumstances.

10/00870 Theoretical and experimental analysis of the thermal behaviour of a green roof system installed in two residential buildings in Athens, Greece

Sfakianaki, A. *et al. International Journal of Energy Research*, 2009, 33, (12), 1059–1069.

Measurements of the thermal behaviour of two residential buildings equipped with a green roof system have been performed in Athens, Greece. Experimental data have been used to calibrate detailed simulation tools and the specific energy and environmental performance of the planted roofs system has been estimated in detail. Simulations have been performed for free-floating and thermostatically controlled conditions. The expected energy benefits as well as the possible improvements of the indoor thermal comfort have been assessed. It is found that green roofs have a limited contribution to the heating demand of insulated buildings operating under the Mediterranean climate. On the contrary, the green roof system is found to contribute highly to reduce the cooling load of thermostatically controlled buildings. For the considered residential buildings, a cooling load decrease of about 11% has been calculated. In parallel, it is found that green roofs contribute to improve thermal comfort in free-floating buildings during the summer period. The expected maximum decrease of the indoor air and roof surface temperatures is close to 0.6°C. Such a decrease contributes to reduce by 0.1 the summer absolute Predicted Mean Vote Comfort Index levels in the building.

10/00871 Theoretical performance assessment of an integrated photovoltaic and earth air heat exchanger greenhouse using energy and exergy analysis methods

Nayak, S. and Tiwari, G. N. *Energy and Buildings*, 2009, 41, (8), 888–896.

In this paper, a simplified mathematical model develops to study round the year effectiveness of photovoltaic/thermal (PV/T) and earth air heat exchanger (EAHE) integrated with a greenhouse, located at IIT Delhi, India. The solar energy application through photovoltaic system and earth air heat exchanger (EAHE) for heating and cooling of a greenhouse is studied with the help of this simplified mathematical model. Calculations are done for four types of weather conditions (a, b, c and d types) in New Delhi, India. The paper compares greenhouse air temperatures when it is operated with photovoltaic/thermal (PV/T) during daytime coupled with earth air heat exchanger (EAHE) at night, with air temperatures when it is operated exclusively with photovoltaic/thermal system (PV/T) and earth air heat exchanger (EAHE), for 24 h. The results reveal that air temperature inside the greenhouse can be increased by around 7–8 °C during winter season, when the system is operated with photovoltaic (PV/T), coupled with earth air heat exchanger (EAHE) at night. From the results, it is seen that the hourly useful thermal energy generated, during daytime and night, when the system is operated with photovoltaic (PV/T) coupled with earth air heat exchanger (EAHE), is 33 MJ and 24.5 MJ, respectively. The yearly thermal energy generated by the system has been calculated to be 24728.8 kWh, while the net electrical energy savings for the year is 805.9 kWh and the annual thermal exergy energy generated is 1006.2 kWh.

10/00872 Generation of high-purity hydrogen from cellulose by its mechanochemical treatment

Zhang, Q. *et al. Bioresource Technology*, 2009, 100, (15), 3731–3733.

Cellulose was mixed with the hydroxides of lithium and nickel and the mixture was milled, followed by heating to produce hydrogen. Several analytical methods of X-ray diffraction (XRD), thermogravimetry/mass spectrometry (TG/MS) and gas chromatography (GC) were used to characterize the samples. Hydrogen was emitted when heating the milled sample around 400 °C together with low concentrations of methane, carbon monoxide and carbon dioxide. It is understood that an interaction occurs between cellulose and lithium hydroxide to convert the carbon of cellulose into lithium carbonate and to emit hydrogen correspondingly. It is also found that nickel catalyst is required to facilitate the interaction and the behaviours of three different nickel compounds were compared. When high yield of hydrogen emission is available, the prepared samples can also serve the purpose of hydrogen storage.

14 FUEL SCIENCE AND TECHNOLOGY

Fundamental science, analysis, instrumentation

10/00873 A GIS-based stand management system for estimating local energy wood supplies

Vainio, P. *et al. Biomass and Bioenergy*, 2009, 33, (9), 1278–1288.

A GIS-based system for decision support in wood procurement management was developed in order to identify energy wood harvesting alternatives during the integrated planning of harvesting operations. The system uses the information content of existing stand databases and an estimation method which is based on three major modules: (i) modelling of energy wood volumes, (ii) modelling of costs of haulage to the roadside and road transportation, and (iii) economical allocation analysis of material flows. An application of this technology demonstrates how estimation of the total potential of residuals for local energy use can be integrated into wood procurement planning in Finland. Three experiments were prepared for testing this application. Based on the thinning regulations laid down by the Finnish national forest management organization Tapio, wood harvesting on permanent sample plots was simulated by two alternative procedures, one based on the empirical diameter distribution and the other on a theoretical Weibull distribution derived from the mean variables. The effects of these procedures on the extent of the residual energy wood potential were investigated. The third test compared this system with another system often used in Finland. The experimental results suggest that the theoretical distribution produces unreliable estimates in the case of untreated or young stands. Furthermore, the conventional system underestimates the potential of the residual energy wood. The implications of these results for improving the strategic planning of energy wood procurement in Finland are discussed.

10/00874 A global optimization study on the devolatilisation kinetics of coal, biomass and waste fuels

Pantoleontos, G. *et al. Fuel Processing Technology*, 2009, 90, (6), 762–769.

Kinetic modelling of the pyrolysis of coal, biomass and waste fuels is presented using a power-law model in terms of multiple parallel reactions. The behaviour of the overall conversion rate of the pyrolysis products is derived from the summation of each reaction's conversion rate, while the exponential integral for the computation of individual conversion is evaluated by Hastings rational approximation. Global optimization techniques and the global optimization toolbox for Maple were used in order to minimize globally the sum of squares of errors. Comparison with literature results derived using local scope search methods supports the assumption that the problem is non-convex, thus necessitating the use of global optimization, which leads to a very good agreement between the computational and experimental values of the overall conversion rate vs temperature derived from a non-isothermal thermogravimetric analyser.

10/00875 A homogeneous flow model for boiling heat transfer calculation based on single phase flow

Li, G. *et al. Energy Conversion and Management*, 2009, 50, (7), 1862–1868.

By means of the concept of void fraction, a homogeneous flow model for boiling heat transfer is established from the change of void fraction in the tiny hexahedral element of the flow field. The model is based on the assumption that the boiling liquid field is a single phase flow in which vapour and liquid are homogeneously mixed, with void fraction being calculation basis to reflect boiling heat transfer, therefore, the concept of single phase flow can be used to calculate boiling heat transfer problems. After validated with the reported experimental results, as a calculation instance, the numerical simulation of boiling heat transfer process of engine cooling water-jacket in cylinder head is carried out, which indicates the void fraction distribution in cooling passage. The result shows that heat transfer coefficient considering boiling factor is evidently different from that of pure heat convection, and the maximum deviation can be more than 50%.

10/00876 A model for estimation of daylight factor for skylight: an experimental validation using pyramid shape skylight over vault roof mud-house in New Delhi (India)

Chel, A. *et al. Applied Energy*, 2009, 86, (11), 2507–2519.

A model to estimate daylight factor was investigated and validated using experimental hourly inside and outside illuminance data of an existing skylight integrated vault roof mud-house in composite climate of New Delhi. The daylight factor model was found in good agreement with experimental value of daylight factor. This model was modified for different practical horizontal surface levels inside the big and small dome rooms and validated using experimental measured data. The yearly average value of percentage daylight factor for big and small dome skylight rooms was determined as 2% and 6%, respectively. The total annual average artificial lighting energy saving potential of the skylight illuminance in the existing building was estimated as 973 kW h/year; corresponds to 1526 kg/year of CO_2 emission mitigation. Hence, the annual carbon credit potential from skylight mud-house building is €15.3/year.

10/00877 A supply and demand based volatility model for energy prices

Kanamura, T. *Energy Economics*, 2009, 31, (5), 736–747.

This paper proposes a new volatility model for energy prices using the supply–demand relationship, which is called a supply and demand based volatility model. The authors show that the supply curve shape in the model determines the characteristics of the volatility in energy prices. It is found that the inverse Box–Cox transformation supply curve reflecting energy markets causes the inverse leverage effect, i.e. positive correlation between energy prices and volatility. The model is also used to show that an existing (G)ARCH-M model has the foundations on the supply–demand relationship. Additionally, the authors conduct empirical studies analysing the volatility in US natural gas prices.

10/00878 Algorithms and analytical solutions for rapidly approximating long-term dispersion from line and area sources

Barrett, S. R. H. and Britter, Rex *Atmospheric Environment*, 2009, 43, (20), 3249–3258.

Predicting long-term mean pollutant concentrations in the vicinity of airports, roads and other industrial sources are frequently of concern in regulatory and public health contexts. Many emissions are represented geometrically as ground-level line or area sources. Well-developed modelling tools such as AERMOD and ADMS are able to model dispersion from finite (i.e. non-point) sources with considerable accuracy, drawing upon an up-to-date understanding of boundary layer behaviour. Due to mathematical difficulties associated with line and area sources, computationally expensive numerical integration schemes have been developed. For example, some models decompose area sources into a large number of line sources orthogonal to the mean wind direction, for which an analytical (Gaussian) solution exists. Models also employ a time-series approach, which involves computing mean pollutant concentrations for every hour over one or more years of meteorological data. This can give rise to computer runtimes of several days for assessment of a site. While this may be acceptable for assessment of a single industrial complex, airport, etc., this level of computational cost precludes national or international policy assessments at the level of detail available with dispersion modelling. In this paper, the authors extend previous work to line and area sources. They introduce approximations which allow for the development of new analytical solutions for long-term mean dispersion from line and area sources, based on hypergeometric functions. The authors describe how these solutions can be parameterized from a single point source run from an existing advanced dispersion model, thereby accounting for all processes modelled in the more costly algorithms. The parameterization method combined with the analytical solutions for long-term mean dispersion are shown to produce results several orders of magnitude more efficiently with a loss of accuracy small compared to the absolute accuracy of advanced dispersion models near sources. The method can be readily incorporated into existing dispersion models, and may allow for additional computation time to be expended on modelling dispersion processes more accurately in future, rather than on accounting for source geometry.

10/00879 Application of energy rating methods to the existing building stock: analysis of some residential buildings in Turin

Ballarini, I. and Corrado, V. *Energy and Buildings*, 2009, 41, (7), 790–800.

The objective of this work is to contribute to the recent standardization activity, finalized to apply the Energy Performance of Buildings Directive (EPBD). Through the energy assessment of some residential buildings in Turin, Italy, the work investigates the application of the calculation methods that have been specified in the recent European standard for the so-called 'standard energy rating'. A comparison of the 'calculated energy rating' with the 'measured energy rating' is used to investigate the effect of user behaviour and weather conditions. Moreover, in order to draft the energy certificate and make an appropriate classification, the last part of the work investigates the way to find energy reference values of the building stock, through the study of the correlation between the input and the output data of an energy rating and the comparison of the analysed buildings.

10/00880 Classification of daily solar radiation distributions using a mixture of Dirichlet distributions

Soubdhan, T. *et al. Solar Energy*, 2009, 83, (7), 1056–1063.

In order to characterize the fluctuating nature of solar radiation in tropical climate, this study classified daily distributions of the clearness index k_t by estimating a finite mixture of Dirichlet distributions without assuming any parametric hypothesis on these daily distributions. The method is applied to solar radiation measurements performed in Guadeloupe (16°2N, 61W) where important fluctuations can be observed even within a period of a few minutes. The results exhibit four distinct classes of distributions corresponding to different types of days. The sequence of such classes can be of interest for future weather prediction.

10/00881 Development of a mathematical model for a curved slat venetian blind with thickness

Chaiyapinunt, S. and Worasinchai, S. *Solar Energy*, 2009, 83, (7), 1093–1113.

In this study a model is used for determining the performance of a glass window installed with a venetian blind in term of heat transmission. The blind, whose optical properties are considered nonspecular, is modelled as an effective layer, . The optical properties of the effective layer are mainly dependent on the slat angle, slat properties and solar profile angle. The effect of slat curvature and the effect of slat thickness are included in the developed model. The shortwave optical properties of the effective layer, transmittance, reflectance and absorptance, are classified as the optical properties for direct radiation and the optical properties for diffuse radiation. The analysis for optical properties due to the interreflection of the direct radiation between the adjacent slat surfaces is done by using the radiosity method on a six surface closed enclosure. The effect of the slat curvature and thickness causes the shaded area blocked by the blind itself to increase in certain cases. The optical properties for diffuse radiation of the effective layer are determined by considering the incident diffuse radiation from the sky and from the ground. The optical properties calculated from the developed model are also compared to the results obtained from the three previous models. The results predicted by the developed mathematical model are compared with the experimental results. The ratio of the transmitted radiation through the glass window installed with the venetian blind to the incident radiation on the glass window is used to validate this study. It is shown from the comparison that the developed mathematical model for the venetian blind including the curvature and thickness effect yields quite accurate predicted results.

10/00882 Development of a numerical hydraulic model of the Los Azufres steam pipeline network

García-Gutiérrez, A. *et al. Geothermics*, 2009, 38, (3), 313–325.

The development and documentation of a hydraulic model of the steam pipeline network at the Los Azufres geothermal field is presented, as well as the results obtained using one- and two-phase numerical simulators. Flow simulations were performed to determine pressure and heat losses, flow directions and velocities in that network. Computed well pressures agree within ±10% with measured values, except in three of the 41 wells in the system where the differences are between 10% and 13%. Computed and measured steam flow rates entering the Los Azufres geothermal power plants agree within 10%, with the exception of one that showed a 26.7% difference. This is most likely due to a mismatch between the reported and actual flow rates delivered by the pipeline network. The computed results are considered highly satisfactory given the complexity of the Los Azufres network.

10/00883 Endogenous implementation of technology gap in energy optimization models – a systematic analysis within TIMES G5 mode

Rout, U. K. *et al. Energy Policy*, 2009, 37, (7), 2814–2830.

Evaluation of global diffusion potential of learning technologies and their timely specific cost development across regions is always a challenging issue for the future technology policy preparation. Further the process of evaluation gains interest especially by endogenous treatment of energy technologies under uncertainty in learning rates with technology gap across the regions in global regional cluster learning approach. This work devised, implemented, and examined new methodologies on technology gaps (a practical problem), using two broad concepts of knowledge deficit and time lag approaches in global learning, applying the floor cost approach methodology. The study was executed in a multi-regional, technology-rich and long horizon bottom-up linear energy system model on The Integrated MARKAL EFOM System (TIMES) framework. Global learning selects highest learning technologies in maximum uncertainty of learning rate scenario, whereas any form of technology gap retards the global learning process and discourages the technologies deployment. Time lag notions of technology gaps prefer heavy utilization of learning technologies in developed economies for early reduction of specific cost. Technology gaps of any kind should be reduced among economies through the promotion and enactment of various policies by governments, in order to utilize the technological resources by mass deployment to combat ongoing climate change.

10/00884 Exergy concept and its application to the built environment

Shukuya, M. *Building and Environment*, 2009, 44, (7), 1545–1550.

This paper discusses how a built environmental control system such as space heating and cooling can be described by the concept of 'exergy', which quantifies what is consumed by any working systems from man-made systems such as heat engines or buildings to biological systems including human body. The reason for the intensive and extensive use of exergy concept is to deepen the understanding of the built environment and thereby to develop a variety of low-exergy systems for future buildings. First, the essence of exergy balance equations is reviewed and then some results obtained from the recent exergy research were presented. The important findings described in this paper are as follows: (1) a volume of indoor air contains both of 'warm' or 'cool' exergy and of 'wet' or 'dry' exergy, whose values are comparable to each other especially for a hot and humid summer condition; (2) an ordinary air-source heat pump is basically a device to separate exergy supplied by electricity into warm, cool and dry exergies by consuming more than 85% of the supplied exergy; (3) there is a set of a little higher mean radiant temperature and a little lower air temperature, which provides with the lowest human body exergy consumption rate in winter season; (4) availability of cool radiant exergy of 20–40 $\mathrm{mW/m^2}$ seems to play a key role for thermal comfort in a naturally ventilated room in summer season; and (5) 'cool' radiant exergy available from the sky in hot and humid regions amounts to 1000 $\mathrm{mW/m^2}$, which is not necessarily small if compared to the values of cool radiant exergy to be supplied indoors.

10/00885 Hybrid method of moments for modeling soot formation and growth

Mueller, M. E. *et al. Combustion and Flame*, 2009, 156, (6), 1143–1155.

In this work, a new statistical model for soot formation and growth is developed and presented. The hybrid method of moments (HMOM) seeks to combine the advantages of two moment methods, the method of moments with interpolative closure (MOMIC) and the direct quadrature method of moments (DQMOM), in an accurate and consistent formulation. MOMIC is numerically simple and easy to implement but is unable to account for bimodal soot number density functions (NDF). DQMOM is accurate but is numerically ill-posed and difficult to implement. HMOM combines the best of both two methods to capture bimodal NDF while retaining ease of implementation and numerical robustness. The new hybrid method is shown to predict mean quantities nearly as accurately as DQMOM and high-fidelity Monte Carlo simulations. In addition, a model for combining particle coalescence with particle aggregation is presented and shown to accurately reproduce experimental measurements in a variety of sooting flames.

10/00886 INLUX: a calculation code for daylight illuminance predictions inside buildings and its experimental validation

De Rosa, A. *et al. Building and Environment*, 2009, 44, (8), 1769–1775.

A calculation code, named INLUX, able to predict the average illuminance on the inside surfaces of a room with six walls and a window, is presented. The walls and the window are subdivided into a given number of small areas, identified by the coordinates of their centres. The code solves, at each desired instant, the system of the illuminance equations of each surface element, characterized by its reflection coefficient and its view factors toward the other elements. It is assumed that all surfaces reflect the light in a diffuse manner. The model belongs to the calculation models classified as 'radiosity models' The code was validated by comparing the calculated values of illuminance with the experimental values measured inside a scale model (1:5) of a building room, located outdoors, in overcast sky conditions. The validation, performed using the sky luminance data measured by a sky scanner as input data, showed a good performance of the code.

10/00887 Local heat transfer coefficients and pressure gradients for R-134a during flow boiling at temperatures between $-9\,^\circ$C and $+20\,^\circ$C

de Rossi, F. *et al. Energy Conversion and Management*, 2009, 50, (7), 1714–1721.

This study presents new flow boiling heat transfer and pressure gradient results of R-134a flowing inside a 6.00 mm internal diameter, smooth and horizontal stainless steel tube. The measurements were made over a wide range of test conditions, where there is a lack of data in literature for the investigated geometry: evaporating pressure from 2.1 to 5.7 bar (saturation temperature between $-8.8\,^\circ$C and $19.9\,^\circ$C), refrigerant mass flux from 197 to 472 $\text{kg m}^{-2}\text{s}^{-1}$ and heat flux from 8.5 to 20.1 kW m^{-2}. The experimental results allow to evaluate the dependence of the heat transfer coefficients and pressure gradients on the vapour quality, the saturation temperature, the refrigerant mass flux and heat flux. The new database of 254 points it is used determine the best predictive methods for heat transfer coefficients and pressure gradients; indeed, it is presented an analysis of the influence of the saturation pressure and of the mass flux on the error of these predictive methods.

10/00888 Mass and energy-capital conservation equations to study price evolution of non-renewable energy resources, Part III – energy supply curve

Gori, F. *Applied Thermal Engineering*, 2009, 29, (11–12), 2172–2186.

The price evolution of non-renewable resources versus the consumption rate is investigated with the aim of constructing the energy supply curve. The case studied is without accumulation nor depletion of the resources and the mass and energy-capital conservation equations are solved under the condition of the same mass flow rate of extraction and sale. The energy supply curve of extracted resource is dependent on the newly defined parameter, RINE, rate of interest of non-extracted resources on the extraction rate. The energy supply curve of sold resource is dependent on the newly defined parameter, RISE, rate of interest of sold resources on the extraction rate, in case the rate of interest of non-extracted resources, r_N, is nil. In general, the energy supply curve of sold resource is dependent also on two dimensionless parameters, dimensionless critical initial price of sold resources (DCIPS), and dimensionless critical initial price extreme of sold resources (DCIPES). The energy supply curve of sold resources is investigated under different relations between three parameters, i.e. extraction rate and interest rates of non-extracted and extracted/sold resources. New trends are observed in the economic market of non-renewable energy resources. The energy supply curve of the difference between sold and extracted resource is also obtained and is dependent on two dimensionless parameters, critical initial price difference (CIPD), and critical extreme of the initial price difference (CEIPD). Finally, the predictions obtained with the present approach are compared to the real evolution of the world price of oil and the European price of gas versus the world consumption during the last three decades, i.e. from 1980 until 2005 for oil and from 1984 until 2005 for gas, taking into account inflation, discount and prime rates of the economic market. The agreement is acceptable but, more important, the trend is correctly predicted. The price difference between sold and extracted resources is also investigated versus the dimensionless mass flow rate of extraction. The evolution is dependent on four parameters: RINE, RISE, DCIPS, and DCIPES.

10/00889 Modeling technological change in energy systems – from optimization to agent-based modeling

Ma, T. and Nakamori, Y. *Energy*, 2009, 34, (7), 873–879.

Operational optimization models are one of the main streams in modelling energy systems. Agent-based modelling and simulation seem to be another approach getting popular in this field. In either optimization or agent-based modelling practices, technological change in energy systems is a very important and inevitable factor that researchers need to deal with. By introducing three stylized models, namely, a traditional optimization model, an optimization model with endogenous technological change, and an agent-based model, all of which were developed based on the same deliberately simplified energy system, this paper compares how technological change is treated differently in different modelling practices for energy systems, the different philosophies underlying them, and the advantages/disadvantages of each modelling practice. Finally, this paper identifies the different contexts suitable for applying optimization models and agent-based models in decision support regarding energy systems.

10/00890 Modeling the land requirements and potential productivity of sugarcane and jatropha in Brazil and India using the LPJmL dynamic global vegetation model

Lapola, D. M. *et al. Biomass and Bioenergy*, 2009, 33, (8), 1087–1095.

The governments of Brazil and India are planning a large expansion of bioethanol and biodiesel production in the next decade. Considering that limitation of suitable land and/or competition with other land uses might occur in both countries, assessments of potential crop productivity can contribute to an improved planning of land requirements for biofuels under high productivity or marginal conditions. This study models the potential productivity of sugarcane and jatropha in both countries. Land requirements for such expansions are calculated according to policy scenarios based on government targets for biofuel production in 2015. Spatial variations in the potential productivity lead to rather different land requirements, depending on where plantations are located. If jatropha is not irrigated, land requirements to fulfil the Indian government's plans in 2015 would be of 410,000 to 95,000 km^2 if grown in low or high productivity areas respectively (mean of 212,000 km^2). In Brazil land requirements, are of 18,000–89,000 km^2 (mean of 29,000 km^2), suggesting a promising substitute to soybean biodiesel. Although future demand for sugarcane ethanol in Brazil is approximately ten times larger than in India, land requirements are comparable in both countries due to large differences in ethanol production systems. In Brazil this requirement ranges from 25,000 to 211,000 km^2 (mean of 33,000 km^2) and in India from 7000 to 161,000 km^2 (mean 17,000 km^2). Irrigation could reduce the land requirements by 63% and 41% (24% and 15%) in India (Brazil) for jatropha and sugarcane, respectively.

10/00891 Monte Carlo simulation and benchmarking of pulsed neutron experiments in variable buckling BeO systems

Sohrabpour, M. and Ezzati, A. O. *Annals of Nuclear Energy*, 2009, 36, (5), 547–549.

Pulsed neutron decay simulation of BeO moderator as a result of injecting 14 MeV neutron pulses into finite size systems are carried out with the MCNP Monte Carlo code. The simulated decay constants as compared against a previous experimental work showed variations of about 2%. The resulting decay constants and the fitted diffusion coefficients based on the simulation results are found to agree with the experimental results within a margin of about 4%.

10/00892 Numerical determination of adequate air gaps for building-integrated photovoltaics

Gan, G. *Solar Energy*, 2009, 83, (8), 1253–1273.

The efficiency of photovoltaic (PV) devices is approximately inversely proportional to the cell temperature and the air gap of PV modules over or beside a building envelope can facilitate ventilation cooling of building-integrated photovoltaics. The effect of gap size on the performance of one type of PV module (with dimensions 1209 mm × 537 mm × 50 mm) in terms of cell temperature has been determined numerically for a range of roof pitches and panel lengths under two different settings of solar heat gains. It has been found that under constant solar heat gain, the air velocity behind PV modules due to natural convection in general increases with roof pitch angle. For a given location where solar heat gain varies with inclination from horizontal plane, however, the air velocity increases up to a pitch angle of about 60 degrees and then decreases with increasing roof pitch. The mean and maximum PV temperatures decrease with the increase in pitch angle and air gap. The mean PV temperature also decreases with increasing panel length for air gaps greater than or equal to 0.08 m, whereas the maximum PV temperature generally increases with panel length but decreases when the length of a roof-mounted panel increases from two modules to three modules and the air gap is between 0.1 and 0.11 m. Without adequate air circulation, overheating of PV modules would occur and hot spots could form near the top of modules with potential cell temperatures over 80 °C above ambient air temperature under bright sunshine.

10/00893 Optimal corrective actions for power systems using multi-objective genetic algorithms

Abou EL Ela, A. A. and Spea, S. R. *Electric Power Systems Research*, 2009, 79, (5), 722–733.

In this paper, optimal corrective control actions are presented to restore the secure operation of power system for different operating conditions. Genetic algorithm (GA) is one of the modern optimization techniques, which has been successfully applied in various areas in power systems. Most of the corrective control actions involve simultaneous optimization of several objective functions, which are competing and conflicting each other. The multi-objective genetic algorithm (MOGA) is used to optimize the corrective control actions. Three different procedures based on GA and MOGA are proposed to alleviate the violations of the overloaded lines and minimize the transmission line losses for different operation conditions. The first procedure is based on corrective switching of the transmission lines and generation re-dispatch. The second procedure is carried out to determine the optimal siting and sizing of distributed generation (DG). While, the third procedure is concerned into solving the generation-load imbalance problem using load shedding. Numerical simulations are carried out on two test systems in order to examine the validity of the proposed procedures.

10/00894 Piezoelectric energy harvesting

Howells, C. A. *Energy Conversion and Management*, 2009, 50, (7), 1847–1850.

Piezoelectric materials can be used to convert oscillatory mechanical energy into electrical energy. This technology, together with innovative mechanical coupling designs, can form the basis for harvesting energy from mechanical motion. Piezoelectric energy can be harvested to convert walking motion from the human body into electrical power. Recently four proof-of-concept heel strike units were developed where each unit is essentially a small electric generator that utilizes piezoelectric elements to convert mechanical motion into electrical power in the form factor of the heel of a boot. The results of the testing and evaluation and the performance of this small electric generator are presented. The generator's conversion of mechanical motion into electrical power, the processes it goes through to produce useable power and commercial applications of the Heel Strike electric generator are discussed.

10/00895 Sensitivity of the total heat loss coefficient determined by the energy signature approach to different time periods and gained energy

Sjögren, J.-U. *et al. Energy and Buildings*, 2009, 41, (7), 801–808.

In this study, a linear regression approach (energy signature) has been used to analyse data for 2003–2006 for nine fairly new multifamily buildings located in the Stockholm area, Sweden. The buildings are heated by district heating and the electricity used is for household equipment and the buildings' technical systems. The data consist of monthly energy used for heating and outdoor temperature together with annual water use, and for some buildings data for household electricity are also available. For domestic hot water and electricity, monthly distributions have been assumed based on data from previous studies and energy companies. The impact on K_{tot} and T_{i} of the time period and assumed values for the utilized energy are investigated. The results show that the obtained value of K_{tot} is rather insensitive to the time period and utilized energy if the analysis is limited to October–March, the period of the year when the solar radiation in Sweden yields a minor contribution to heating. The results for the total heat loss coefficient were also compared to the calculations performed in the design stage; it was found that K_{tot} was on average 20% larger and that the contribution to heating from solar radiation was substantially lower than predicted. For the indoor temperature, however, the utilized energy had a large impact. With access to an estimate of K_{tot} and T_{i}, an improved evaluation of the energy performance may be achieved in the Swedish real estate market. At present the measure commonly used, despite the fact that monthly data is available, is the annual use of energy for space heating per square metre of area to let.

10/00896 System optimization for HVAC energy management using the robust evolutionary algorithm

Fong, K. F. *et al. Applied Thermal Engineering*, 2009, 29, (11–12), 2327–2334.

For an installed centralized heating, ventilating and air conditioning (HVAC) system, appropriate energy management measures would achieve energy conservation targets through the optimal control and operation. The performance optimization of conventional HVAC systems may be handled by operation experience, but it may not cover different optimization scenarios and parameters in response to a variety of load and weather conditions. In this regard, it is common to apply the suitable simulation–optimization technique to model the system then determine the required operation parameters. The particular plant simulation models can be built up by either using the available simulation programs or a system of mathematical expressions. To handle the simulation models, iterations would be involved in the numerical solution methods. Since the gradient information is not easily available due to the complex nature of equations, the traditional gradient-based optimization methods are not applicable for this kind of system models. For the heuristic optimization methods, the continual search is commonly necessary, and the system function call is required for each search. The frequency of simulation function calls would then be a time-determining step, and an efficient optimization method is crucial, in order to find the solution through a number of function calls in a reasonable computational period. In this study, the robust evolutionary algorithm (REA) is presented to tackle this nature of the HVAC simulation models. REA is based on one of the paradigms of evolutionary algorithm, evolution strategy, which is a stochastic population-based searching technique emphasized on mutation. The REA, which incorporates the Cauchy deterministic mutation, tournament selection and arithmetic recombination, would provide a synergetic effect for optimal search. The REA is effective to cope with the complex simulation models, as well as those represented by explicit mathematical expressions of HVAC engineering optimization problems.

10/00897 Thermodynamic analysis of glycerol dry reforming for hydrogen and synthesis gas production

Wang, X. *et al. Fuel*, 2009, 88, (11), 2148–2153.

A thermodynamic analysis of glycerol dry reforming has been performed by the Gibbs free energy minimization method as a function of CO_2 to glycerol ratio, temperature, and pressure. Hydrogen and synthesis gas can be produced by the glycerol dry reforming. The carbon neutral glycerol reforming with greenhouse gas CO_2 could convert CO_2 into synthesis gas or high value-added inner carbon. Atmospheric pressure is preferable for this system and glycerol conversion keeps 100%. Various of H_2/CO ratios can be generated from a flexible operational range. Optimized conditions for hydrogen production are temperatures over 975 K and CO_2 to glycerol ratios of 0–1. With a temperature of 1000 K and CO_2 to glycerol ratio of 1, the production of synthesis gas reaches a maximum, e.g. 6.4 mol of synthesis gas ($H_2/CO = 1:1$) can be produced per mole of glycerol with CO_2 conversion of 33%.

10/00898 Thermodynamic analysis of the reverse Joule–Brayton cycle heat pump for domestic heating

White, A. J. *Applied Energy*, 2009, 86, (11), 2443–2450.

The paper presents an analysis of the effects of irreversibility on the performance of a reverse Joule–Brayton cycle heat pump for domestic heating applications. Both the simple and recuperated (regenerative) cycle are considered at a variety of operating conditions corresponding to traditional (radiator) heating systems and low-temperature underfloor heating. For conditions representative of typical central heating in the UK, the simple cycle has a low work ratio and so very high compression and expansion efficiencies and low pressure losses are required to obtain a worthwhile COP. An approximate analysis suggests that these low loss levels would not necessarily be impossible to achieve, but further investigation is required, particularly regarding irreversible heat transfer to and from cylinder walls. In principle, recuperation improves the cycle work ratio, thereby making it less susceptible to losses, but in practice this advantage is compromised when realistic values of recuperator effectiveness are considered.

10/00899 Uniqueness verification of solar spectrum index of average photon energy for evaluating outdoor performance of photovoltaic modules

Minemoto, T. *et al. Solar Energy*, 2009, 83, (8), 1294–1299.

To analyse the effect of a spectral irradiance distribution of solar spectra on the outdoor performance of photovoltaic (PV) modules, an index for the spectral distribution is needed. Average photon energy (APE), which represents the average energy per photons included in a spectrum, is one of these. In this study, the uniqueness of APE to the spectral irradiance distribution was statistically analysed to assure that an APE value uniquely yields the shape of a solar spectrum. The similar methodology adopted in International Electrotechnical Commission to rate the spectral matching of a solar simulator was used for the analysis. The results showed that an APE value yielded a spectral irradiance distribution with quite small standard deviation. The analysis using APE showed that the outdoor performance of crystalline Si PV modules depended almost only on a module temperature, while that of amorphous Si ones mainly depended on APE. The behaviours were reasonable considering from the operation mechanisms of the PV modules. These results demonstrate that APE is a reasonable and useful index to describe the spectral irradiance distribution for evaluating the outdoor performance of PV modules.

10/00900 Weighting methodologies in multi-criteria evaluations of combined heat and power systems

Wang, J.-J. *et al. International Journal of Energy Research*, 2009, 33, (12), 1023–1039.

Several combined heat and power (CHP) system options are presented to assess and compare with respect to the end users' requirements. According to the obtained data from literature, 16 kinds of CHP systems are evaluated using grey relational method in multi-criteria, such as technology, economy, environment, and society. The results depend greatly on the criteria weights in multi-criteria evaluations. Aiming to obtain rational result, this paper reviews the weighting method briefly and proposes an optimal combined weighting method to consider the subjectivity of decision-maker and the objectivity of measurement data. The singular value decomposition aggregation method is employed to verify the rationality of evaluation result. Through multi-criteria evaluation and discussions, the combination weighting method is recommended for the selection of CHP schemes. Finally, the best CHP system is selected and the most conspicuous factors having great impact on CHP system with respect to the users' requirements are given out.

Fuel cell technology

10/00901 Ammonia as efficient fuel for SOFC

Fuerte, A. *et al. Journal of Power Sources*, 2009, 192, (1), 170–174.
Ammonia is a possible candidate as the fuel for SOFCs. In this work, the influence on the performance of a tubular SOFC running on ammonia is studied. Analysis of open circuit voltages (OCVs) on the cell indicated the oxidation of ammonia within a SOFC is a two-stage process: decomposition of the inlet ammonia into nitrogen and hydrogen, followed by oxidation of hydrogen to water. For comparison, cell was also tested with hydrogen as the fuel and air as oxidant at different temperatures showing a similar behaviour. The performance of the cell tested under various conditions shows the high potential of ammonia as fuel for SOFCs.

10/00902 An alternative way of estimating anodic and cathodic transfer coefficients from PEMFC polarization curves

Danilov, V. A. and Tade, M. O. *Chemical Engineering Journal*, 2009, 156, (2), 496–499.
This study presents a new technique for estimating cathodic and anodic charge transfer coefficients from fuel cell voltage–current curves. In contrast to conventional approach, the new technique allows estimation of anodic and cathodic charge transfer coefficients simultaneously from integral characteristics of voltage–current curves. Case studies illustrate the parameter estimation from PEMFC polarization curves. The new technique is compatible with available parameter estimation methods.

10/00903 Assembly pressure and membrane swelling in PEM fuel cells

Zhou, Y. *et al. Journal of Power Sources*, 2009, 192, (2), 544–551.
Assembly pressure and membrane swelling induced by elevated temperature and humidity cause inhomogeneous compression and performance variation in proton exchange membrane (PEM) fuel cells. This research conducts a comprehensive analysis on the effects of assembly pressure and operating temperature and humidity on PEM fuel cell stack deformation, contact resistance, overall performance and current distribution by advancing a model previously developed by the authors. First, a finite element model (FEM) model is developed to simulate the stack deformation when assembly pressure, temperature and humidity fields are applied. Then a multi-physics simulation, including gas flow and diffusion, proton transport, and electron transport in a three-dimensional cell, is conduced. The modelling results reveal that elevated temperature and humidity enlarge gas diffusion layer (GDL) and membrane inhomogeneous deformation, increase contact pressure and reduce contact resistance due to the swelling and material property change of the GDL and membrane. When an assembly pressure is applied, the fuel cell overall performance is improved by increasing temperature and humidity. However, significant spatial variation of current distribution is observed at elevated temperature and humidity.

10/00904 Characterization and optimization of an autothermal diesel and jet fuel reformer for 5 kW$_e$ mobile fuel cell applications

Karatzas, X. *et al. Chemical Engineering Journal*, 2009, 156, (2), 366–379.
The present paper describes the characterization of an autothermal reformer designed to generate hydrogen by autothermal reforming (ATR) from commercial diesel fuel (~10 ppm S) and jet fuel (~200 ppm S) for a $5\,kW_e$ polymer electrolyte fuel cell (PEFC). Commercial noble metal-based catalysts supported on 900 cpsi cordierite monoliths substrates were used for ATR with reproducible results. Parameters investigated in this study were the variation of the fuel inlet temperature, fuel flow and the H_2O/C and O_2/C ratios. Temperature profiles were studied both in the axial and radial directions of the reformer. Product gas composition was analysed using gas chromatography. It was concluded from the experiments that an elevated fuel inlet temperature ($\geq 60\,^\circ C$) and a higher degree of fuel dispersion, generated via a single-fluid pressurized-swirl nozzle at high fuel flow, significantly improved the performance of the reformer. Complete fuel conversion, a reforming efficiency of 81% and an H_2 selectivity of 96% were established for ATR of diesel at $P = 5\,kW_e$, $H_2O/C = 2.5$, $O_2/C = 0.49$ and a fuel inlet temperature of 60 °C. No hot-spot formation and negligible coke formation were observed in the reactor at these operating conditions. The reforming of jet fuel resulted in a reforming efficiency of only 42%. A plausible cause is the coke deposition, originating from the aromatics present in the fuel, and the adsorption of S-compounds on the active sites of the reforming catalyst. These results indicate possibilities for the developed catalytic reformer to be used in mobile fuel cell applications for energy-efficient hydrogen production from diesel fuel.

10/00905 Comparative study of oxygen reduction reaction on $Ru_xM_ySe_z$ (M = Cr, Mo, W) electrocatalysts for polymer exchange membrane fuel cell

Suárez-Alcántara, K. and Solorza-Feria, O. *Journal of Power Sources*, 2009, 192, (1), 165–169.
Electrochemical evaluation of the $Ru_xM_ySe_z$ (M = Cr, Mo, W) type electrocatalysts towards the oxygen reduction reaction (ORR) is presented. The electrocatalysts were synthesized by reacting the corresponding transition metal carbonyl compounds and elemental selenium in 1,6-hexanediol under refluxing conditions for 3 h. The powder electrocatalysts were characterized by scanning electron microscopy (SEM), and X-ray diffraction. Results indicate the formation of agglomerates of crystalline particles with nanometric size embedded in an amorphous phase. The particle size decreased according to the following trend: $Ru_xCr_ySe_z > Ru_xW_ySe_z > Ru_xMo_ySe_z$. Electrochemical studies were performed by rotating disk electrode and rotating ring-disk electrode techniques. Kinetic parameters exhibited Tafel slopes of $120\,mV\,dec^{-1}$; exchange current density of around $1 \times 10^{-5}\,mA\,cm^{-2}$ and apparent activation energies between 40 and $55\,kJ\,mol^{-1}$. A four-electron reduction was found in all three cases. The catalytic activity towards the ORR decreases according to the following trend: $Ru_xMo_ySe_z > Ru_xW_ySe_z > Ru_xCr_ySe_z$. However this trend was not maintained when the materials were tested as cathode electrodes in a single polymer exchange membrane fuel cell. The $Ru_xW_ySe_z$ electrocatalyst showed poor activity compared to $Ru_xMo_ySe_z$ and $Ru_xCr_ySe_z$ which were considered suitable candidates to be used as cathode in polymer exhange membrane fuel cells.

10/00906 Development of an air bleeding technique and specific duration to improve the CO tolerance of proton-exchange membrane fuel cells

Chung, C.-C. *et al. Applied Thermal Engineering*, 2009, 29, (11–12), 2518–2526.
This study investigated transient CO poisoning of a proton-exchange membrane fuel cell under either a fixed cell voltage or fixed current density. During CO poisoning tests, the cell performance decreases over time. Experiments were performed to identify which method yields better performance in CO poisoning tests. The results revealed that a change in cell voltage did not affect the stable polarization behaviour after CO poisoning of the cell. On the other hand, a higher fixed current density yielded better tolerance of 52.7 ppm CO. The air bleeding technique was then applied using different timings for air introduction during CO poisoning tests. Air bleeding significantly improved the CO tolerance of the cell and recovered the performance after poisoning, regardless of the timing of air introduction. The effects of different anode catalyst materials on cell performance were also investigated during poisoning tests. Without air bleeding, a Pt–Ru alloy catalyst exhibited better CO tolerance than a pure Pt catalyst. However, the air bleeding technique can effectively increase the CO tolerance of cells regardless of the type of catalyst used.

10/00907 Effect of cathode GDL characteristics on mass transport in PEM fuel cells

Park, S. and Popov, B. N. *Fuel*, 2009, 88, (11), 2068–2073.
The effect of the content of the hydrophobic agent in the cathode gas diffusion layer (GDL) on the mass transport in the proton exchange membrane fuel cells (PEMFCs) was studied using mercury porosimetry, scanning electron microscopy, and electrochemical polarization techniques. The mercury intrusion data and SEM micrograph indicated that the hydrophobic agent alters the surface and bulk structure of the GDL, thereby controlling gas-phase void volume and liquid water transport. The electrochemical polarization curves were measured and quantitatively analysed to determine the oxygen transport limitation both in the catalyst layer and the GDL. Evaluation of the parameter ζ, which represents the cathode GDL characteristics for liquid water transport, indicated that the optimized content of the hydrophobic agent and effective water management results from a trade-off between the hydrophobicity and the absolute permeability for faster water drainage.

10/00908 Effect of increasing anode surface area on the performance of a single chamber microbial fuel cell

Di Lorenzo, M. *et al. Chemical Engineering Journal*, 2009, 156, (1), 40–48.

The anode material and its configuration represent an important parameter in a microbial fuel cell (MFC), as it influences the development of the microbial community involved in the electrochemical bio-reactions. The aim of this work was to evaluate single chamber microbial fuel cells (SCMFCs) with high anode surface area, achieved by using packed beds of irregular graphite granules. The performance of the SCMFC with the packed bed anode configuration was studied using a mixed microorganism culture from real wastewaters in batch and continuous mode operation. The current output was found to increase with the increase in thickness of the anode bed and with the approximate anode area. The best performance was obtained with the 3 cm anode bed depth SCMFC. When the latter was operated in batch mode, Coulombic efficiencies varied from 30% to 74%, depending upon feed COD. In continuous mode operation, the COD removal was 89% and Coulombic efficiency 68% with a feed COD of 50 ppm, and at a flow rate of 0.0028 $cm^3 min^{-1}$. Power performance was also reasonable with a volumetric power density of 1.3 $W m^{-3}$, with respect to the net anodic volume (12.5 cm^3). Comparable performance was achieved with real wastewater. Over the duration of tests current output was stable. The investigation performed in this study represent a step forward for implementing real applications of MFC technology. A model of the current distribution in the packed bed electrode was applied, which correlates the effective utilization of the electrode to its specific area, solution conductivity and slope of the polarization curve. This model could function as a starting point in designing appropriate electrode geometries.

10/00909 Entropy generation analysis in a monolithic-type solid oxide fuel cell (SOFC)

Sciacovelli, A. and Verda, V. *Energy*, 2009, 34, (7), 850–865.

The aim of the paper is to investigate possible improvements in the geometry design of a monolithic solid oxide fuel cells through analysis of the entropy generation terms. The different contributions to the local rate of entropy generation are calculated using a computational fluid dynamic model of the fuel cell, accounting for energy transfer, fluid dynamics, current transfer, chemical reactions and electrochemistry. The fuel cell geometry is then modified to reduce the main sources of irreversibility and increase its efficiency.

10/00910 High surface area graphite as alternative support for proton exchange membrane fuel cell catalysts

Ferreira-Aparicio, P. *et al. Journal of Power Sources*, 2009, 192, (1), 57–62.

The suitability of a high surface area graphite (HSAG) as a proton exchange membrane fuel cell (PEMFC) catalyst support has been evaluated and compared with that of the most popular carbon black: the Vulcan XC72. It has been observed that Pt is arranged on the graphite surface resulting in different structures which depend on the catalysts synthesis conditions. The influence that the metal particle size and the metal-support interaction exert on the catalysts degradation rate is analysed. Temperature programmed oxidation (TPO) under oxygen containing streams has been shown to be a useful method to assess the resistance of PEMFC catalysts to carbon corrosion. The synthesized Pt/HSAG catalysts have been evaluated in single cell tests in the cathode catalytic layer. The obtained results show that HSAG can be a promising alternative to the traditionally used Vulcan XC72 carbon black when suitable catalysts synthesis conditions are used.

10/00911 Modeling of transport, chemical and electrochemical phenomena in a cathode-supported SOFC

Ho, T. X. *et al. Chemical Engineering Science*, 2009, 64, (12), 3000–3009.

This paper investigates the performance of a planar cathode-supported solid oxide fuel cell (SOFC) with composite electrodes using a detailed numerical model. The methane reforming reaction is included in the model and takes place mostly in the porous, thin anode at the high operating temperature of 800–1000 °C. A single computational domain comprises the fuel and air channels and the electrodes–electrolyte assembly eliminating the need for internal boundary conditions. The equations governing transport and chemical and electrochemical processes for mass, momentum, chemical and charged species and energy are solved using Star-CD augmented by subroutines written in-house. The operating cell voltage is determined by the potential difference between the cathode and the anode, whose potentials are fixed. Results of temperature, chemical species, current density and electric potential distribution for a co-flow configuration are shown and discussed. It is found that the sub-cooling effect observed in anode-supported cells is almost ameliorated, making the cathode-supported cell favourable from the viewpoint of material stability.

10/00912 Multi-walled carbon nanotubes modified by sulfated TiO_2 – a promising support for Pt catalyst in a direct ethanol fuel cell

Guo, D.-J. *et al. Carbon*, 2009, 47, (7), 1680–1685.

This study reports the synthesis of multi-walled carbon nanotubes coated with sulfated TiO_2 (S–TiO_2/MWCNTs) as a promising support for Pt catalyst in a direct ethanol fuel cell. Highly dispersed Pt nanoparticles were supported on the S–TiO_2/MWCNT composites by $NaBH_4$ reduction procedure (Pt–S–TiO_2/MWCNTs). The presence and nature of the catalyst were characterized by Fourier transform infrared spectroscopy, X-ray diffraction, high-resolution transmission electron microscopy. The size of the sulfated TiO_2 product was about 8 nm, and that of the Pt nanoparticle on the S–TiO_2/MWCNT composites was about 5 nm. The Pt–S–TiO_2/MWCNTs were used to study the electrochemical ethanol oxidation reaction using cyclic voltammetry, chronoamperometry and impedance spectroscopy. The results show that Pt–S–TiO_2/MWCNT catalysts show higher catalytic activity for ethanol oxidation compared with Pt supported on non-sulfated TiO_2/MWCNT composites and commercial Pt/C catalysts.

10/00913 On the repeatability and reproducibility of experimental two-chambered microbial fuel cells

Larrosa, A. *et al. Fuel*, 2009, 88, (10), 1852–1857.

The capability of the experimental systems used in two-chambered microbial fuel cell experimentation was tested in terms of repeatability and reproducibility. The optimal number of replicates needed to discriminate between responses of technical interest, both in open-circuit and closed-circuit experiments was studied. For $N = 4$ replicates, these differences were set to 9.0% COD_R units, 261 mV and 63 mg/L in VFAs for open-circuit experiments and 3.6%, 30.2 mV and 45 mg/L in closed circuit experiments. Cycling operation with several reactor refills using fresh wastewater and keeping the same biofilm between cycles almost has no influence in COD_R and VFAs but voltage standard deviation reduces by one half between the first and fourth cycle. This study takes part by the option of increasing the number of replicates because although it may have lower repeatability, the amount of data generated per unit time is larger than running the experiments in cycles.

10/00914 On-chip direct methanol fuel cells of a monolithic design: consideration on validity of active-type system

Tominaka, S. *et al. Energy & Environment Science*, 2009, 2, (2), 845–848.

The performance of an on-chip direct methanol fuel cell of monolithic design with an active-type system was improved more than six-fold up to >100 μW by using hydrogen peroxide as an oxidant solution instead of dissolved oxygen, but the energy-loss caused by strong capillary forces required a redesign of both microchannel size and the system.

10/00915 On-chip fuel cells for safe and high-power operation: investigation of alcohol fuel solutions

Tominaka, S. *et al. Energy & Environment Science*, 2009, 2, (2), 849–852.

An on-chip fuel cell, of membraneless, air-breathing and monolithic design, was proven to operate on a different fuel (methanol, ethanol or 2-propanol) solution containing an acidic ion-conductor (sulfuric acid) or a neutral one (phosphate buffer).

10/00916 Parametric exergy analysis of a tubular solid oxide fuel cell (SOFC) stack through finite-volume model

Calise, F. *et al. Applied Energy*, 2009, 86, (11), 2401–2410.

This paper presents a very detailed local exergy analysis of a tubular solid oxide fuel cell (SOFC) stack. In particular, a complete parametric analysis has been carried out, in order to assess the effects of the synthesis/design parameters on the local irreversiblities in the components of the stack. A finite-volume axial-symmetric model of the tubular internal reforming SOFC stack under investigation has been used. The stack consists of: SOFC tubes, tube-in-tube pre-reformer and tube and shell catalytic burner. The model takes into account the effects of heat/mass transfer and chemical/electrochemical reactions. The model allows one to predict the performance of a SOFC stack once a series of design and operative parameters are fixed, but also to investigate the source and localization of inefficiency. To this scope, an exergy analysis was implemented. The SOFC tube, the pre-reformer and the catalytic burner are discretized along their longitudinal axes. Detailed models of the kinetics of the reforming, catalytic combustion and electrochemical reactions are implemented. Pressure drops, convection heat transfer and overvoltages are calculated on the basis of the work previously developed by the authors. The heat transfer model includes the contribution of thermal radiation, so improving the models previously used by the authors. Radiative heat transfer is calculated on the basis of the slice-to-slice configuration factors and corresponding radiosities. On the basis of this thermochemical model, an exergy analysis has been carried out, in order to localize the sources and the magnitude of irreversibilities along the components of the stack. In addition, the main synthesis/design variables were varied in order to assess their effect on the exergy destruction within the component to which the parameter directly refers ('endogenous' contribution) and on the exergy destruction of all remaining components ('exogenous' contribution). Then, this analysis is used to detect the parameters to be optimized in order to reduce the overall irreversibility rate in the cell.

10/00917 Pt nanoparticle stability in PEM fuel cells: influence of particle size distribution and crossover hydrogen

Holby, E. F. *et al. Energy & Environment Science*, 2009, 2, (2), 865–871.
This work demonstrates the essential role of particle size and crossover hydrogen on the degradation of platinum polymer electrolyte membrane fuel cell (PEMFC) cathodes. One of the major barriers to implementation of practical PEMFCs is the degradation of the cathode catalyst under operating conditions. This work combines both experimental and theoretical techniques to develop a validated and thermodynamically consistent kinetic model for the coupling of degradation and the catalyst particle size distribution. The model demonstrates that, due to rapid changes in the Gibbs–Thomson energy, particle size effects dominate degradation for 2 nm particles but play almost no role for 5 nm particles. This result can help guide synthesis of more stable distributions. The authors also identify the effect of hydrogen molecules that cross over from the anode, demonstrating that in the presence of this crossover hydrogen surface area loss is greatly enhanced. The authors demonstrate that crossover hydrogen changes the surface area loss mechanism from coarsening to platinum loss through dissolution and precipitation off of the carbon support.

10/00918 Scale effect and two-phase flow in a thin hydrophobic porous layer. Application to water transport in gas diffusion layers of proton exchange membrane fuel cells

Rebai, M. and Prat, M. *Journal of Power Sources*, 2009, 192, (2), 534–543.
Pore network simulations are performed to study water transport in gas diffusion layers (GDLs) of polymer electrolyte membrane fuel cells (PEMFCs). The transport and equilibrium properties are shown to be scale dependent in a thin system like a GDL. A distinguishing feature of such a thin system is the lack of length scale separation between the system size and the size of the representative elementary volume (REV) over which are supposed to be defined the macroscopic properties within the framework of the continuum approach to porous media. Owing to the lack of length scale separation, two-phase flow traditional continuum models are expected to offer poor predictions of water distribution in a GDL. This is illustrated through comparisons with results from the pore network model. The influence of inlet boundary conditions on invasion patterns is studied and shown to affect greatly the saturation profiles. The effects of GDL differential compression and partial coverage of outlet surface are also investigated.

10/00919 Self-regulating passive fuel supply for small direct methanol fuel cells operating in all orientations

Paust, N. *et al. Journal of Power Sources*, 2009, 192, (2), 442–450.
A microfluidic fuel supply concept for passive and portable direct methanol fuel cells (DMFCs) that operates in all spatial orientations is presented. The concept has been proven by fabricating and testing a passive DMFC prototype. Methanol transport at the anode is propelled by the surface energy of deformed carbon dioxide bubbles, generated as a reaction product during DMFC operation. The experimental study reveals that in any orientation, the proposed pumping mechanism transports at least 3.5 times more methanol to the reactive area of the DMFC than the stoichiometry of the methanol oxidation would require to sustain DMFC operation. Additionally, the flow rates closely follow the applied electric load; hence the pumping mechanism is self-regulating. Oxygen is supplied to the cathode by diffusion and the reaction product water is transported out of the fuel cell along a continuous capillary pressure gradient. Results are presented that demonstrate the continuous passive operation for more than 40 h at ambient temperature with a power output of $p = 4\,\mathrm{mW\,cm^{-2}}$ in the preferred vertical orientation and of $p = 3.2\,\mathrm{mW\,cm^{-2}}$ in the least favourable horizontal orientation with the anode facing downwards.

10/00920 Stirling based fuel cell hybrid systems: an alternative for molten carbonate fuel cells

Sánchez, D. *et al. Journal of Power Sources*, 2009, 192, (1), 84–93.
This paper presents a new design for high temperature fuel cell and bottoming thermal engine hybrid systems. Now, instead of the commonly used gas turbine engine, an externally fired – Stirling – piston engine is used, showing outstanding performance when compared to previous designs. First, a comparison between three thermal cycles potentially usable for recovering waste heat from the cell is presented, concluding the interest of the Stirling engine against other solutions used in the past. Secondly, the interest shown in the previous section is confirmed when the complete hybrid system is analysed. Advantages are not only related to pure thermal and electrochemical parameters like specific power or overall efficiency. Additionally, further benefits can be obtained from the atmospheric operation of the fuel cell and the possibility to disconnect the bottoming engine from the cell to operate the latter on stand-alone mode. This analysis includes on design and off design operation.

10/00921 Three-dimensional CFD modelling of PEM fuel cells: an investigation into the effects of water flooding

Dawes, J. E. *et al. Chemical Engineering Science*, 2009, 64, (12), 2781–2794.
In this work, a three-dimensional PEM fuel cell model has been developed and is used to investigate the effects of water flooding on cell performance parameters. The presence of liquid water in the cathode gas diffusion layer (GDL) limits the flow of reactants to the cathode catalyst layer, thereby reducing the overall reaction rate and curtailing the maximum power that can be derived from the cell. To characterize the effects of water flooding on gas diffusion, effective diffusivity models that account for the tortuosity and relative water saturation of the porous fuel cell electrodes have been derived from percolation theory and coupled with the CFD model within a single phase flow skeleton. The governing equations of the overall three-dimensional PEM fuel cell model, which are a representative of the coupled CFD and percolation theory based effective diffusivity models, are then solved using the finite volume method. Parametric studies have been conducted to characterize the effects of GDL permeability, inlet humidity and diffusivity of the reactants on the various cell performance parameters such as concentration of reactants/products and cell current densities. It is determined that the GDL permeability has little or no effect on the current densities due to the diffusion dominated nature of the gas flow. However, through the incorporation of percolation theory based effective diffusivity model; a marked reduction in the cell performance is observed which closely resembles published experimental observations. This is a reasonable approximation for effects of water flooding which has been inherently used for further parametric studies.

10/00922 Two-phase modeling of mass transfer characteristics of a direct methanol fuel cell

He, Y.-L. *et al. Applied Thermal Engineering*, 2009, 29, (10), 1998–2008.
A two-dimensional, two-phase mass transport model has been developed for a direct methanol fuel cell (DMFC). The model is numerically solved with an in-house code and validated with published experimental data in the literature. In particular, gaseous and liquid phase velocities in the anode porous structure are obtained so that the liquid–gas counter convection effect can be investigated. The numerical results show that the mass transfer of methanol is predominated by the resistance in the anode porous structure, which is affected by physical properties of the porous medium, such as porosity, permeability, and contacting angle. It is further shown that cell performance can be improved by increasing the porosity and permeability, and decreasing the contacting angle of the porous medium for a given feed methanol concentration.

15 ENVIRONMENT

Pollution, health protection, applications

10/00923 An experimental study on the environmental performance of the automated blind in summer

Kim, J.-H. *et al. Building and Environment*, 2009, 44, (7), 1517–1527.
Blinds are used widely in numerous buildings to conserve energy and provide for occupants' comfort in the perimeter zone. However, manual or motorized blinds are limited in their ability to reduce energy consumption and to provide comfort because occupants themselves must operate blinds to block direct solar radiation. Thus, the use of automated blinds would more fully exploit the full benefits of blinds. This study aims to find out whether the environmental performance of a building can be improved by the application of an automated venetian blind in comparison to a manual or motorized venetian blind and whether occupants may feel discomfort by the application of an automated venetian blind in the summer season. This study also aims to find out the insufficiency of the automatic control algorithm of that automated venetian blind for future study of the development of that

algorithm. Through this study, the potential energy savings and the comfort enhancement when using the automated blind was confirmed and the insufficiency of the automatic control algorithm of that was also found out.

10/00924 Climate forcing by the on-road transportation and power generation sectors

Unger, N. *et al. Atmospheric Environment*, 2009, 43, (19), 3077–3085.

The on-road transportation (ORT) and power generation (PG) sectors are major contributors to carbon dioxide (CO_2) emissions and a host of short-lived radiatively active air pollutants, including tropospheric ozone and fine aerosol particles, that exert complex influences on global climate. Effective mitigation of global climate change necessitates action in these sectors for which technology change options exist or are being developed. Most assessments of possible energy change options to date have neglected non-CO_2 air pollutant impacts on radiative forcing (RF). In a multi-pollutant approach, the authors applied a global atmospheric composition-climate model to quantify the total RF from the global and United States (US) ORT and PG sectors. The RF was assessed for two time horizons: 20- and 100-year that were relevant for understanding near-term and longer-term impacts of climate change, respectively. ORT is a key target sector to mitigate global climate change because the net non-CO_2 RF is positive and acts to enhance considerably the CO_2 warming impacts. The authors performed further sensitivity studies to assess the RF impacts of a potential major technology shift that would reduce ORT emissions by 50% with the replacement energy supplied either by a clean zero-emissions source (S1) or by the PG sector, which results in an estimated 20% penalty increase in emissions from this sector (S2). Cases were examined where the technology shift is applied globally and in the USA only. The resultant RF relative to the present day control is negative (cooling) in all cases for both S1 and S2 scenarios, global and US emissions, and 20- and 100-year time horizons. The net non-CO_2 RF is always important relative to the CO_2 RF and outweighs the CO_2 RF response in the S2 scenario for both time horizons. Assessment of the full impacts of technology and policy strategies designed to mitigate global climate change must consider the climate effects of ozone and fine aerosol particles.

10/00925 Community-based approaches to strategic environmental assessment: lessons from Costa Rica

Sinclair, A. J. *et al. Environmental Impact Assessment Review*, 2009, 29, (3), 147–156.

This paper describes a community-based approach to strategic environmental assessment (SEA) using a case study of the Instituto Costarricense de Electricidad's (ICE) watershed management agricultural program (WMAP) in Costa Rica. The approach focused on four highly interactive workshops that used visioning, brainstorming and critical reflection exercises. Each workshop represented a critical step in the SEA process. Through this approach, communities in two rural watersheds assessed the environmental, social and economic impacts of a proposed second phase for WMAP. Lessons from this community-based approach to strategic environmental assessment include a recognition of participants learning what a participatory SEA is conceptually and methodologically; the role of interactive techniques for identifying positive and negative impacts of the proposed program and generating creative mitigation strategies; the effect of workshops in reducing power differentials among program participants (proponent, communities, government agencies); and, the logistical importance of notice, timing and location for meaningful participation. The community-based approach to SEA offers considerable potential for assessing regional (watershed) development programs focused on sustainable resource-based livelihoods.

10/00926 Costly myths: an analysis of idling beliefs and behavior in personal motor vehicles

Carrico, A. R. *et al. Energy Policy*, 2009, 37, (8), 2881–2888.

Despite the large contribution of individuals and households to climate change, little has been done in the USA to reduce the CO_2 emissions attributable to this sector. Motor vehicle idling among individual private citizens is one behaviour that may be amenable to large-scale policy interventions. Currently, little data are available to quantify the potential reductions in emissions that could be realized by successful policy interventions. In addition, little is known about the motivations and beliefs that underlie idling. In the fall of 2007, 1300 drivers in the USA were surveyed to assess typical idling practices, beliefs and motivations. Results indicate that the average individual idled for over 16 min a day and believed that a vehicle can be idled for at least 3.6 min before it is better to turn it off. Those who held inaccurate beliefs idled, on average, over 1 min longer than the remainder of the sample. These data suggest that idling accounts for over 93 MMt of CO_2 and 10.6 billion gallons (40.1 billion litres) of gasoline a year, equalling 1.6% of all US emissions. Much of this idling is unnecessary and economically disadvantageous to drivers. The policy implications of these findings are discussed.

10/00927 Decomposing road freight energy use in the United Kingdom

Sorrell, S. *et al. Energy Policy*, 2009, 37, (8), 3115–3129.

Applying the techniques of decomposition analysis, this study estimates the relative contribution of 10 variables (termed 'key ratios') plus GDP to the change in UK road freight energy use over the period 1989–2004 inclusive. The results are best interpreted as an estimate of the percentage growth in energy consumption that would have resulted from the change in the relevant factor (e.g. length of haul) had the other factors remained unchanged. The results demonstrate that the main factor contributing to the decoupling of UK road freight energy consumption from GDP was the decline in the value of domestically manufactured goods relative to GDP. Over the period 1989–2004 this largely offset the effect of increases in GDP on road freight energy consumption. While the decline in domestic manufacturing was to some extent displaced by increases in imports, the net effect of these supply factors, together with shifts in the commodity mix, has been to reduce UK road freight energy consumption by 30.1%. The net effect on global carbon dioxide (CO_2) emissions is likely to be somewhat less beneficial, since many freight movements associated with the manufacture of imported goods have simply been displaced to other countries.

10/00928 Development of thermodynamically-based models for simulation of hydrogeochemical processes coupled to channel flow processes in abandoned underground mines

Kruse, N. A. and Younger, P. L. *Applied Geochemistry*, 2009, 24, (7), 1301–1311.

Accurate modelling of changing geochemistry in mine water can be an important tool in post-mining site management. The pollutant sources and sinks in underground mines (POSSUM) model and pollutant loadings above average pyrite influenced geochemistry POSSUM (PLAYING POSSUM) model were developed using object-oriented programming techniques to simulate changing geochemistry in abandoned underground mines over time. The conceptual model was created to avoid significant simplifying assumptions that decrease the accuracy and defensibility of model solutions. POSSUM and PLAYING POSSUM solve for changes in flow rate and depth of flow using a finite difference hydrodynamics model then, subsequently, solve for geochemical changes at distinct points along the flow path. Geochemical changes are modelled based on a suite of 28 kinetically controlled mineral weathering reactions. Additional geochemical transformations due to reversible sorption, dissolution and precipitation of acid generating salts and mineral precipitation are also simulated using simplified expressions. Contaminant transport is simulated using a novel application of the random-walk method. By simulating hydrogeochemical changes with a physically and thermodynamically controlled model, the 'state of the art' in post-mining management can be advanced.

10/00929 Emissions trading in China: a conceptual 'leapfrog' approach?

Raufer, R. and Li, S. *Energy*, 2009, 34, (7), 904–912.

China is well aware of the advantages of quantity-based economic instruments (i.e. emissions trading) for domestic pollution control, but pilot studies and experimental programs in Taiyuan, Hong Kong/Guangdong, and other locations have not been successful. This paper proposes a very different type of emissions trading program, designed with Chinese implementation concerns in mind. It has three component parts: (1) a real-time intermittent control system (ICS) strategy designed to address public health concerns in the near term; (2) software-oriented predictive emissions monitoring systems targeting process parameter (rather than emission) reporting from individual emission sources; and (3) real-time emissions markets responding to the ICS constraint. The technical and political difficulties associated with implementing such a system are recognized as daunting. However, such an approach would 'leapfrog' over existing systems, allowing the country to develop a comprehensive air pollution control strategy as economic growth occurs, continuously improving air quality in a cost efficient manner, utilizing both advanced technology and market-based control approaches in a manner consistent with China's unique environmental needs. It would also lay the groundwork for the eventual pricing of CO_2 and other greenhouse gases within China.

10/00930 Energy use in Indian household sector – an actor-oriented approach

Reddy, B. S. and Srinivas, T. *Energy*, 2009, 34, (8), 992–1002.

Over the years, significant changes have taken place with regard to the type as well the quantity of energy used in Indian households. Many factors have contributed in bringing these changes. These include availability of energy, security of supplies, efficiency of use, cost of device, price of energy carriers, ease of use, and external factors like technological development, introduction of subsidies, and environmental considerations. The present paper presents the pattern of energy consumption in the household sector and analyses the causalities underlying the present usage patterns. It identifies specific (groups of) actors, study their specific situations, analyse the constraints and discusses opportunities for improvement. This can be referred to 'actor-oriented' analysis in which we understand how various actors of the energy system are making the system work, and what incentives and constraints each of these actors is experiencing. It analyses actor linkages and their impact on the fuel choice mechanism. The study shows that the role of actors in household fuel choice is significant and depends on the level of factors – micro, meso and macro. It is recommended that the development interventions should include actor-oriented tools in energy planning, implementation, monitoring and evaluation. The analysis is based on the data from the national sample survey (NSS), India. This approach provides a spatial viewpoint which permits a clear assessment of the energy carrier choice by the households and the influence of various actors. The scope of the paper is motivated and limited by suggesting and formulating a powerful analytical technique to analyse the problem involving the role of actors in the Indian household sector.

10/00931 Environmental assessment of natural radionuclides and heavy metals in waters discharged from a lignite-fired power plant

Karamanis, D. *et al. Fuel*, 2009, 88, (10), 2046–2052.

Gross alpha, gross beta and ^{226}Ra activities as well as the concentration of trace metals (V, Cr, Mn, Ni, Cu, Zn, Mo and Pb) in the discharge waters of the major lignite-fired power plant in Greece were measured during the period October 2004 to May 2006. Gross alpha activity of particulate matter in the discharge waters was 0.75 ± 0.40 Bq g^{-1} (0.3–1.2 Bq g^{-1}) while the beta activity was 1.54 ± 0.50 Bq g^{-1} (1.2–1.7 Bq g^{-1}). The ranges of water gross alpha, beta and ^{226}Ra activities were 0.062–0.268 Bq L^{-1}, 0.064–0.268 Bq L^{-1} and 0.021–0.062 Bq L^{-1}, respectively. The mean concentration of ^{226}Ra in the discharge waters was at least one order of magnitude higher than in natural water bodies. Soil samples were collected from fields irrigated with discharge waters and 29.2 ± 2.2 Bq kg^{-1} of ^{238}U, 1.2 ± 0.2 Bq kg^{-1} of ^{235}U, 26.8 ± 0.8 Bq kg^{-1} of ^{226}Ra, 36.8 ± 1.5 Bq kg^{-1} of ^{232}Th and 492.6 ± 25.8 Bq kg^{-1} of ^{40}K were determined. The concentration values of dissolved metals in the discharge waters were higher than those usually observed in water streams near coal-fired power plants or rivers due to metal leaching from lignite or/and by-products. However, the leaching at high pHs as those observed in the discharged waters does not raise the concentration of the studied metals to values higher than the criteria maximum concentrations and criterion continuous concentration (CCC) values of the US EPA water quality criteria. Statistical analysis was further applied to reveal the correlations between the different water components. Hierarchical cluster analysis revealed four different clusters: the first cluster was primarily composed of radioactivity and physicochemical parameters; the second cluster consisted of Cu, Ni and Zn, the third of Mn, Fe, Mo and Pb and the fourth of V and Cr. This clustering agrees with the associations suggested for elements in most coals or with the Goldschmidt classification.

10/00932 Estimation of passive cooling efficiency for environmental design in Brazil

Oliveira, J. T. *et al. Energy and Buildings*, 2009, 41, (8), 809–813.

An estimation of passive cooling techniques was conducted for 14 cities in Brazil, using a fairly accurate algorithm that accounts for heat conduction, convection, radiation, and evaporation; this was done to determine the amount of heat gain/loss of room air, defined as a particular quantitative index for passive techniques. Heat gains and losses were calculated for four envelope conditions – namely, insulated, high-albedo, wet surface, and a combination of the previous two – and compared to a case assumed to be the standard condition. A conclusion drawn was that a passive design is efficient in decreasing the need for cooling in typical dwellings in Brazil; solutions should differ with regional climate characteristics. In semi-arid areas, evaporative cooling showed the best results. Reduced heat gain was found during the warm seasons for all cities, along with increased heat gain during the cool seasons for mid-latitude cities. In particular, a combination of high-albedo enveloping and evaporation can greatly decrease heat gain in building walls. High-albedo surfaces in the sub-tropical areas found in southern Brazil are more efficient. It is suggested that passive techniques should be conceived in such a way so as to work during the cooling season and be disabled during mild ones.

10/00933 Health impact assessment in case of biofuel peat – co-use of environmental scenarios and exposure-response functions

Orru, H. *et al. Biomass and Bioenergy*, 2009, 33, (8), 1080–1086.

Peat will be used more widely for heating in Tartu in Estonia, therefore the potential health effects needed to be assessed. In transition from today's gas heating to burning of peat, the amount of exhaust gases emitted will increase and more than 100,000 people will be exposed to greater health risks. Based on the peat quality data, the emissions were calculated and their dispersion in Tartu was modelled using the air pollution dispersion and deposition model AEROPOL. The AirQ software, developed by the WHO, was used for calculating the health impacts. The number of years of life lost (YLL) due to the emissions from peat burning was estimated to be up to 55.5 in a year within the population of Tartu (101,000 citizens). However, in perspective, this would be about 28 times less than YLL calculated due to emissions from traffic, local heating, etc.

10/00934 Identifying future electricity–water tradeoffs in the United States

Sovacool, B. K. and Sovacool, K. E. *Energy Policy*, 2009, 37, (7), 2763–2773.

Researchers for the electricity industry, national laboratories, and state and federal agencies have begun to argue that the country could face water shortages resulting from the addition of thermoelectric power plants, but have not attempted to depict more precisely where or how severe those shortages will be. Using county-level data on rates of population growth collected from the US Census Bureau, utility estimates of future planned capacity additions in the contiguous United States reported to the US Energy Information Administration, and scientific estimates of anticipated water shortages provided from the US Geologic Survey and National Oceanic and Atmospheric Administration, this paper highlights the most likely locations of severe shortages in 22 counties brought about by thermoelectric capacity additions. Within these areas are some 20 major metropolitan regions where millions of people live. After exploring the electricity–water nexus and explaining the study's methodology, the article then focuses on four of these metropolitan areas – Houston, Texas; Atlanta, Georgia; Las Vegas, Nevada; New York, New York – to deepen an understanding of the water and electricity challenges they may soon be facing. It concludes by identifying an assortment of technologies and policies that could respond to these electricity–water tradeoffs.

10/00935 Modeling Pareto efficient PM10 control policies in Northern Italy to reduce health effects

Pisoni, E. and Volta, M. *Atmospheric Environment*, 2009, 43, (20), 3243–3248.

High PM10 concentrations can cause human health problems, both related to short-term and long-term exposure to particles. In this work the impact of efficient PM10 control problems in Northern Italy is assessed by means of a two-stage methodology. In the first stage a multi-objective optimization approach is applied. The multi-objective problem defines two control objectives (the emission reduction costs and the air quality index) to be minimized varying the decision variables (precursor emission reductions). The solution of the multi-objective problem is the Pareto efficient PM10 control policies. In the second stage, the ExternE methodology is applied to estimate health impacts and external costs for the efficient emission reduction scenarios computed in the first stage. The methodology has been applied over Lombardia region, one of the most polluted areas in Europe.

10/00936 Neurobehavioral approach for evaluation of office workers' productivity: the effects of room temperature

Lan, L. *et al. Building and Environment*, 2009, 44, (8), 1578–1588.

Indoor environment quality has great influence on worker's productivity, and how to assess the effect of indoor environment on productivity remains to be the major challenge. A neurobehavioural approach was proposed for evaluation of office workers' productivity in this paper. The distinguishing characteristic of neurobehavioural approach is its emphasis on the identification and measurement of behavioural changes, for the influence of environment on brain functions manifests behaviourally. Therefore worker's productivity can be comprehensively evaluated by testing the neurobehavioural functions. Four neurobehavioural functions, including perception, learning and memory, thinking, and executive functions were measured with nine representative psychometric tests. The effect of room temperature on performance of neurobehavioural tests was investigated in the laboratory. Four temperatures (19, 24, 27, and 32 °C) were investigated based on the thermal sensation from cold to hot. Signal detection theory was utilized to analyse response bias. It was found that motivated people could maintain high performance for a short time under adverse (hot or cold) environmental conditions. Room temperature affected task performance differentially, depending on the type of tasks. The proposed neurobehavioural approach could be worked to quantitatively and systematically evaluate office workers' productivity.

10/00937 Outdoor air pollution in close proximity to a continuous point source

Klepeis, N. E. *et al. Atmospheric Environment*, 2009, 43, (20), 3155–3167.

Data are lacking on human exposure to air pollutants occurring in ground-level outdoor environments within a few metres of point sources. To better understand outdoor exposure to tobacco smoke from cigarettes or cigars, and exposure to other types of outdoor point sources, the authors performed more than 100 controlled outdoor monitoring experiments on a backyard residential patio in which pure carbon monoxide (CO) was released as a tracer gas for continuous time periods lasting 0.5–2 h. The CO was emitted from a single outlet at a fixed per-experiment rate of 120–400 cc min^{-1} ($\sim$140–450 mg min^{-1}). The authors measured CO concentrations every 15 s at up to 36 points around the source along orthogonal axes. The CO sensors were positioned at standing or sitting breathing heights of 2–5 ft (up to 1.5 ft above and below the source) and at horizontal distances of 0.25–2 m. Real-time air speed, wind direction, relative humidity, and temperature was simultaneously measured at single points on the patio. The ground-level air speeds on the patio were similar to those measured during a survey of 26 outdoor patio locations in five nearby towns. The CO data exhibited a well-defined proximity effect similar to the indoor proximity effect reported in the literature. Average concentrations were approximately inversely proportional to distance. Average CO levels were approximately proportional to source strength, supporting generalization of the results to different source strengths. For example, the authors predicted a cigarette smoker would cause average fine particle levels of approximately 70–110 $\mu g\,m^{-3}$ at horizontal distances of 0.25–0.5 m. It was also found that average CO concentrations rose significantly as average air speed decreased. The authors fitted a multiplicative regression model to the empirical data that predicts outdoor concentrations as a function of source emission rate, source–receptor distance, air speed and wind direction. The model described the data reasonably well, accounting for 50% of the log-CO variability in 5-min CO concentrations.

10/00938 Potential environmental issues of CO_2 storage in deep saline aquifers: Geochemical results from the Frio-I Brine Pilot test, Texas, USA

Kharaka, Y. K. *et al. Applied Geochemistry*, 2009, 24, (6), 1106–1112.

Sedimentary basins in general, and deep saline aquifers in particular, are being investigated as possible repositories for large volumes of anthropogenic CO_2 that must be sequestered to mitigate global warming and related climate changes. To investigate the potential for the long-term storage of CO_2 in such aquifers, 1600 t of CO_2 were injected at 1500 m depth into a 24-m-thick 'C' sandstone unit of the Frio Formation, a regional aquifer in the US Gulf Coast. Fluid samples obtained before CO_2 injection from the injection well and an observation well 30 m updip showed a Na–Ca–Cl type brine with $\sim$93,000 mg/L TDS at saturation with CH_4 at reservoir conditions; gas analyses showed that CH_4 comprised $\sim$95% of dissolved gas, but CO_2 was low at 0.3%. Following CO_2 breakthrough, 51 h after injection, samples showed sharp drops in pH (6.5–5.7), pronounced increases in alkalinity (100–3000 mg/L as HCO_3) and in Fe (30–1100 mg/L), a slug of very high DOC values, and significant shifts in the isotopic compositions of H_2O, DIC, and CH_4. These data, coupled with geochemical modelling, indicate corrosion of pipe and well casing as well as rapid dissolution of minerals, especially calcite and iron oxyhydroxides, both caused by lowered pH (initially $\sim$3.0 at subsurface conditions) of the brine in contact with supercritical CO_2. These geochemical parameters, together with perfluorocarbon tracer gases (PFTs), were used to monitor migration of the injected CO_2 into the overlying Frio 'B', composed of a 4-m-thick sandstone and separated from the 'C' by $\sim$15 m of shale and siltstone beds. Results obtained from the Frio 'B' 6 months after injection gave chemical and isotopic markers that show significant CO_2 (2.9% compared with 0.3% CO_2 in dissolved gas) migration into the 'B' sandstone. Results of samples collected 15 months after injection, however, are ambiguous, and can be interpreted to show no additional injected CO_2 in the 'B' sandstone. The presence of injected CO_2 may indicate migration from 'C' to 'B' through the intervening beds or, more likely, a short-term leakage through the remedial cement around the casing of a 50-year old well. Results obtained to date from four shallow monitoring groundwater wells show no brine or CO_2 leakage through the Anahuac Formation, the regional cap rock.

10/00939 Study on the urban heat island mitigation effect achieved by converting to grass-covered parking

Takebayashi, H. and Moriyama, M. *Solar Energy*, 2009, 83, (8), 1211–1223.

The urban heat island mitigation effect of conversion from asphalt-covered parking areas to grass-covered ones is estimated by observation and calculation. The mean surface temperature in a parking lot is calculated from a thermal image captured by an infrared camera. The sensible heat flux in each parking space is calculated based on the surface heat budget. The reduction in the sensible heat flux is estimated to be approximately 100–150 W m^{-2} during the day and approximately 50 W m^{-2} during the night, in comparison with an asphalt surface. The air temperature reduction by the spread of grass-covered parking areas is calculated to be about 0.1 °C. Furthermore, consideration is given to the appearance of the parking lot, the growth of grass, the effects of the weight of a car and the heat radiated from its engine, the costs of construction and maintenance, etc.

10/00940 The impact of landfilling and composting on greenhouse gas emissions – a review

Lou, X. F. and Nair, J. *Bioresource Technology*, 2009, 100, (16), 3792–3798.

Municipal solid waste is a significant contributor to greenhouse gas emissions through decomposition and life-cycle activities processes. The majority of these emissions are a result of landfilling, which remains the primary waste disposal strategy internationally. As a result, countries have been incorporating alternative forms of waste management strategies such as energy recovery from landfill gas capture, aerobic landfilling (aerox landfills), pre-composting of waste prior to landfilling, landfill capping and composting of the organic fraction of municipal solid waste. As the changing global climate has been one of the major environmental challenges facing the world today, there is an increasing need to understand the impact of waste management on greenhouse gas emissions. This review paper serves to provide an overview on the impact of landfilling (and its various alternatives) and composting on greenhouse gas emissions taking into account streamlined life cycle activities and the decomposition process. The review suggests greenhouse gas emissions from waste decomposition are considerably higher for landfills than composting. However, mixed results were found for greenhouse gas emissions for landfill and composting operational activities. Nonetheless, in general, net greenhouse gas emissions for landfills tend to be higher than that for composting facilities.

10/00941 The opportunity cost of land use and the global potential for greenhouse gas mitigation in agriculture and forestry

Golub, A. *et al. Resource and Energy Economics*, 2009, 31, (4), 299–319.

This paper analyses the role of global land management alternatives in determining potential greenhouse gas mitigation by land-based activities in agriculture and forestry. Land-based activities are responsible for over a third of global greenhouse gas emissions, yet the economics of land-use decisions have not been explicitly modelled in global mitigation studies. This study develops a new, general equilibrium framework that effectively captures the opportunity costs of land-use decisions in agriculture and forestry, thereby allowing the analysis of competition for heterogeneous land types across and within sectors, as well as input substitution between land and other factors of production. When land-using sectors are confronted with a tax on greenhouse gas emissions, significant changes were found in the global pattern of comparative advantage across sectors, regions, and land types. Globally, forest carbon sequestration was the dominant strategy for GHG emissions mitigation, while agricultural-related mitigation comes predominantly from reduced methane emissions in the ruminant livestock sector, followed by fertilizer and methane emissions from paddy rice. Regionally, agricultural mitigation is a larger share of total land-use emissions abatement in the USA and China, compared to the rest of the world, and, within agriculture, disproportionately from reductions in fertilizer-related emissions. The results also show how analyses that only consider regional mitigation, may bias mitigation potential by ignoring global market interactions. For example, USA-specific analyses likely over-estimate the potential for abatement in agriculture. Finally, it was noted that this general equilibrium framework provides the research community with a practical methodology for explicit modelling of global land competition and land-based mitigation in comprehensive assessments of greenhouse gas mitigation options.

10/00942 Traffic-generated airborne particles in naturally ventilated multi-storey residential buildings of Singapore: vertical distribution and potential health risks

Kalaiarasan, M. *et al. Building and Environment*, 2009, 44, (7), 1493–1500.

The main objective of the study is to quantify the mass concentration exposure levels of fine traffic-generated particles ($PM_{2.5}$) at various heights of typical multi-storey public housing buildings located in close proximity, i.e. within 30 m and along a busy major expressway in Singapore. The secondary objective is to compare the potential health risks of occupants in the buildings, associated with inhalation exposure of fine traffic-generated particulate matter, based on estimated dose rates and the lowest observed adverse effect levels (loael) at the various floors of these buildings. Two typical public housing buildings, both naturally ventilated residential apartment blocks, of point block configuration (22-storey) and slab block configuration (16-storey) were selected for the study. Particulate samples were collected for both mass and chemical analysis (OC/EC ratio) at three representative floors: the lower, the mid, and upper floors of the buildings. For the potential health risk analysis, the occupants have been divided into four age categories namely, infants, children (1 year), children (8–10 years) and adults. The analysis takes into account age-specific breathing rates, body weights for different age categories. Experimental results explicitly showed that $PM_{2.5}$ mean particle mass concentration was highest at the midfloors of both buildings when compared to those measured at upper and lower floors during a typical day. Although the lower floors were closest to traffic emissions, the mean particle mass concentration was lower there than that at the midfloors, which could presumably be due to the interception of $PM_{2.5}$ particles by tree leaves or the inflow of clean and drier air from higher altitude with lower aerosol burden mixing with the traffic-polluted air at the lower levels thus lowering the concentration at the lower floors similar to induced chimney effect or both. The upper floors had the least fine particulate matter mass concentration due to dilution following pronounced mixing of traffic-polluted air with ambient air. The only difference between both blocks is that at corresponding floors, the mass concentration levels for slab block is much higher than that of point block. This could be attributed to the configuration of the blocks. Observational data show the slab block tends to slow down the approaching wind thus allowing the accumulation of the fine traffic-generated particulate matter in front of the building. For point block, the HR values at the mid and lower floors suggest that occupants living in these floors experience 1.81 and 1.34 times more health risk, respectively, in contracting respiratory diseases when compared to those living at the upper floors for all age categories. Similarly, for the slab block, occupants living in the mid and lower floors had 1.62 and 1.28 times more risk, respectively, in contracting respiratory diseases when compared to those living at the upper floors for all age categories.

10/00943 Using contests to allocate pollution rights

MacKenzie, I. A. *et al. Energy Policy*, 2009, 37, (7), 2798–2806.
This study advocates a new initial allocation mechanism for a tradable pollution permit market. The authors outline a Permit Allocation Contest (PAC) that distributes permits to firms based on their rank relative to other firms. This ranking is achieved by ordering firms based on an observable 'external action' where the external action is an activity or characteristic of the firm that is independent of their choice of emissions in the tradable permit market. It is argued that this mechanism has a number of benefits over auctioning and grandfathering. Using this mechanism efficiently distributes permits, allows for the attainment of a secondary policy objective and has the potential to be more politically appealing than existing alternatives.

10/00944 What energy levels can the Earth sustain?

Moriarty, P. and Honnery, D. *Energy Policy*, 2009, 37, (7), 2469–2838.
Several official reports on future global primary energy production and use develop scenarios which suggest that the high energy growth rates of the 20th century will continue unabated until 2050 and even beyond. This study examines whether any combination of fossil, nuclear, and renewable energy sources can deliver such levels of primary energy – around 1000 EJ in 2050. The authors find that too much emphasis has been placed on whether or not reserves in the case of fossil and nuclear energy, or technical potential in the case of renewable energy, can support the levels of energy use forecast. In contrast, this analysis stresses the crucial importance of the interaction of technical potentials for annual production with environmental factors, social, political, and economic concerns and limited time frames for implementation, in heavily constraining the real energy options for the future. Together, these constraints suggest that future energy consumption will be significantly lower than the present level.

CO_2, NO_x, SO_2 and particulate emissions

10/00945 Application of System Dynamics model as decision making tool in urban planning process toward stabilizing carbon dioxide emissions from cities

Fong, W.-K. *et al. Building and Environment*, 2009, 44, (7), 1528–1537.
In spite of the fact that cities are the main sources of CO_2 emissions, presently there are still no specific measures directly addressing the global warming issue in the urban planning process in Malaysia. The present study thus aims to shed new light in the urban planning sector in Malaysia by adopting the system dynamics model as one of the decision-making tools in the urban planning process, with specific considerations on the future CO_2 emission trends. This paper presented projections of future CO_2 emission trends based on the case of Iskandar Development Region of Malaysia, under various options of urban policies, using the system dynamics model. The projections demonstrated the capability of the said model in serving as a decision-making tool in the urban planning process, with specific reference to CO_2 emissions from cities. Recommendations have been made on the possible approach of adopting the model in the process of structure plan study. If the current model was successfully adopted in the urban planning process in Malaysia, it will mark the first step for Malaysia in taking specific considerations on the issues of CO_2 emissions and global warming in the urban planning process.

10/00946 Catalysis for NO_x abatement

Roy, S. *et al. Applied Energy*, 2009, 86, (11), 2283–2297.
Research in the field of NO_x abatement has grown significantly in the past two decades. The general trend has been to develop new catalysts with complex materials in order to meet the stringent environmental regulations. This review discusses briefly about the different sources of NO_x and its adverse effect on the ecosystem. The main portion of the review discusses the progress and development of various catalysts for NO_x removal from exhaust by NO decomposition, NO reduction by CO or H_2 or NH_3 or hydrocarbons. The importance of understanding the mechanism of NO decomposition and reduction in presence of metal ion substituted catalysts is emphasized. Some conclusions are made on the various catalytic approaches to NO_x abatement.

10/00947 CO_2 emissions change from the sales authorization of diesel passenger cars: Korean case study

Jeong, S. J. *et al. Energy Policy*, 2009, 37, (7), 2630–2638.
The climatic change is a matter of grave concern to the whole world. As a countermeasure against the climatic change convention, the Korean government has authorized the sale of diesel passenger cars since 2005. This study analyses the effects of the sales authorization of diesel passenger cars in its role as a countermeasure. Their share, carbon emissions, and pollutant emissions of each type of passenger car are analysed using system dynamics. The result is that the carbon emissions are decreased by 5.4% but the pollutant emissions are increased by 5%. If the pollutant emissions are controlled, the sales authorization of diesel passenger cars would be a good countermeasure against the climatic change convention.

10/00948 CO_2 emissions structure of Indian economy

Parikh, J. *et al. Energy*, 2009, 34, (8), 1024–1031.
This paper analyses carbon dioxide (CO_2) emissions of the Indian economy by producing sectors and due to household final consumption. The analysis is based on an input–output (IO) table and social accounting matrix (SAM) for the year 2003–2004 that distinguishes 25 sectors and 10 household classes. Total emissions of the Indian economy in 2003–2004 are estimated to be 1217 million tons (MT) of CO_2, of which 57% is due to the use of coal and lignite. The per capita emissions turn out to be about 1.14 tons. The highest direct emissions are due to electricity sector followed by manufacturing, steel and road transportation. Final demands for construction and manufacturing sectors account for the highest emissions considering both direct and indirect emissions as the outputs from almost all the energy-intensive sectors go into the production process of these two sectors. In terms of life style differences across income classes, the urban top 10% accounts for emissions of 3416 kg per year while rural bottom 10% class accounts for only 141 kg per year. The CO_2 emission embodied in the consumption basket of top 10% of the population in urban India is one-sixth of the per capita emission generated in the USA.

10/00949 Does a regional greenhouse gas policy make sense? A case study of carbon leakage and emissions spillover

Chen, Y. *Energy Economics*, 2009, 31, (5), 667–675.
The Regional Greenhouse Gas Initiative (RGGI) is a state-level effort by 10 northeastern states in the USA to control CO_2 emissions from the electric sector. The approach adopted by RGGI is a regional cap-and-trade program, which sets a maximal annual amount of regional CO_2 emissions that can be emitted from the electric sector. However, incoherence of the geographic scope of the regional electricity market is expected to produce two undesirable consequences: CO_2 leakage and NO_x and SO_2 emissions spillover. This paper addresses these two issues using transmission-constrained electricity market models. The results show that although larger CO_2 leakage is associated with higher allowance prices, it is negatively related to CO_2 prices if measured in percentage terms. On the other hand, SO_2 and NO_x emissions spillover increase in commensurate with CO_2 allowance prices. Demand elasticity attenuates the effect of emissions trading on leakage and emissions spillover. This highlights the difficulties of designing a regional or local climate policy.

10/00950 Emission control of nitrogen oxides in the oxy-fuel process

Normann, F. *et al. Progress in Energy and Combustion Science*, 2009, 35, (5), 385–397.
The interest in oxy-combustion as a method to capture carbon dioxide has increased drastically during recent years. The oxy-fuel process offers new process conditions and may take advantage of innovative

techniques as well as of new ways to apply conventional measures for emission control. The present work reviews available techniques for controlling both the emission of nitrogen oxides (NO_x) to the atmosphere and the content of NO_x in the captured carbon dioxide. The results indicate that for a first generation of oxy-fuel power plants, conventional primary NO_x control should be sufficient to meet today's emission regulations, if based on emission per unit of fuel supplied. However, there are several opportunities for new methods of NO_x control in oxy-fuel plants, depending on future emission and storage legislation for carbon capture schemes. Improved understanding of the behaviour of nitric oxide and nitrogen dioxide during compression and condensation of carbon dioxide is needed, as well as improved knowledge on the influence of the parameters of oxy-combustion on nitrogen chemistry.

10/00951 Emission operational strategy for combined cooling, heating, and power systems

Fumo, N. *et al. Applied Energy*, 2009, 86, (11), 2344–2350.

Integrated energy systems (IES), as technology that use thermal activated components to recover waste heat, are energy systems that offer key solution to global warming and energy security through high overall energy efficiency and better fuel use. Combined cooling, heating, and power (CCHP) systems are IES that use recovered thermal energy from the prime mover to produce heating and cooling for the building. The CCHP operational strategy is critical and it has to be considered in a well designed system since it defines the ultimate goal for the benefits expected from the system. One of the most common operational strategies is the cost-oriented strategy, which allows the system to operate at the lowest cost. A primary energy strategy (PES) optimizes energy consumption instead of cost. However, as a result of the worldwide concern about global warming, projects that target reduction of greenhouse gas (GHG) emissions have gained a lot of interest. Therefore, for a CCHP system, an emission strategy (ES) would be an operational strategy oriented to minimize emission of pollutants. In this study, the use of an ES is proposed for CCHP systems targeted to reduce emission of pollutants. The primary energy consumption (PEC) reduction and carbon dioxide (CO_2) emission reduction obtained using the proposed ES are compared with results obtained from the use of a PES. Results show that lower emission of CO_2 is achieved with the ES when compared with the PES, which prove the advantage of the ES for the design of CCHP systems targeted to emissions reduction.

10/00952 Evaluation of the European population intake fractions for European and Finnish anthropogenic primary fine particulate matter emissions

Tainio, M. *et al. Atmospheric Environment*, 2009, 43, (19), 3052–3059.

The intake fraction (iF) has been defined as the integrated incremental intake of a pollutant released from a source category or region summed over all exposed individuals. In this study the authors evaluated the iFs in the population of Europe for emissions of anthropogenic primary fine particulate matter ($PM_{2.5}$) from sources in Europe, with a more detailed analysis of the iF from Finnish sources. Parameters for calculating the iFs include the emission strengths, the predicted atmospheric concentrations, European population data, and the average breathing rate per person. Emissions for the whole of Europe and Finland were based on the inventories of the European Monitoring and Evaluation Programme (EMEP) and the Finnish Regional Emission Scenario (FRES) model, respectively. The atmospheric dispersion of primary $PM_{2.5}$ was computed using the regional-scale dispersion model SILAM. The iFs from Finnish sources were also computed separately for six emission source categories. The iFs corresponding to the primary $PM_{2.5}$ emissions from the European countries for the whole population of Europe were generally highest for the densely populated Western European countries, second highest for the Eastern and Southern European countries, and lowest for the Northern European and Baltic countries. For the entire European population, the iF values varied from the lowest value of 0.31 per million for emissions from Cyprus, to the highest value of 4.42 per million for emissions from Belgium. These results depend on the regional distribution of the population and the prevailing long-term meteorological conditions. Regarding Finnish primary $PM_{2.5}$ emissions, the iF was highest for traffic emissions (0.68 per million) and lowest for major power plant emissions (0.50 per million). The results provide new information that can be used to find the most cost-efficient emission abatement strategies and policies.

10/00953 NO_x emission from a two-stroke ship engine. Part 1: Modeling aspect

Kowalski, J. and Tarelko, W. *Applied Thermal Engineering*, 2009, 29, (11–12), 2153–2159.

International Maritime Organization (IMO) regulations force ship owners to measure NO_x emissions from ship engines, but standard equipped engine rooms do not have any usable apparatus to analyse the exhaust gases. In this paper, the authors propose a method of NO_x emission estimation based on the measurements of working parameters of a two-stroke ship engine. This estimation consists of both the model enabling to determine a temperature, and a model of composition of a gas mixture in the combustion chamber of the engine. The application of such model does not require carrying out direct measurements of engine exhaust gases by exhaust gas analysers. For the developed method, results of engine working parameters should be sufficient to estimate the NO_x emission according to IMO regulations.

10/00954 NO_x emission from a two-stroke ship engine: Part 2 – Laboratory test

Kowalski, J. and Tarelko, W. *Applied Thermal Engineering*, 2009, 29, (11–12), 2160–2165.

International regulations force ship owners to monitor the NO_x emission from engines during sea operational use of ships, but standard equipped engine rooms do not have any measurement equipment to analyse the exhaust gases. According to these regulations, a simple method was proposed to estimate NO_x emissions without direct measurement, based on the measurements of working engine parameters. In this paper, the authors present the results of a laboratory test to verify the adequacy of the developed model. With this aim, tests were carried out on a two-stroke, one-cylinder, and loop scavenged diesel engine. During tests, the engine was operated with the various rotational speeds, loads, and changing air/fuel equivalence ratios. The comparison of the results of calculations with conducted tests showed that the estimation errors in intervals 1.8–11% in dependence from the substitute molar compositions of fuels.

10/00955 On backstops and boomerangs: environmental R&D under technological uncertainty

Goeschl, T. and Perino, G. *Energy Economics*, 2009, 31, (5), 800–809.

In areas such as climate change, the recent economic literature has been emphasizing and addressing the pervasive presence of uncertainty. This paper considers a new and salient form of uncertainty, namely uncertainty regarding the environmental characteristics of 'green' innovations. Here, R&D may generate both backstop technologies and technologies that turn out to involve a new pollution problem ('boomerangs'). In the optimum, R&D will therefore typically be undertaken more than once. Extending results from multi-stage optimal control theory, the authors present a tractable model with a full characterization of the optimal pollution and R&D policies and the role of uncertainty. In this setting, (i) the optimal R&D programme is defined by a research trigger condition in which the decision-maker's belief about the probability of finding a backstop enters in an intuitive way; (ii) a decreasing probability of finding a backstop leads to the toleration of higher pollution levels, slower R&D, a slower turnover of technologies, and an ambiguous effect on the expected number of innovations; (iii) learning about the probability of a backstop is driven by failures only and leads to decreasing research incentives; and (iv) small to moderate delays in the resolution of technological uncertainty do not affect the optimal policy.

10/00956 Particle emission factors during cooking activities

Buonanno, G. *et al. Atmospheric Environment*, 2009, 43, (20), 3235–3242.

Exposure to particles emitted by cooking activities may be responsible for a variety of respiratory health effects. However, the relationship between these exposures and their subsequent effects on health cannot be evaluated without understanding the properties of the emitted aerosol or the main parameters that influence particle emissions during cooking. Whilst traffic-related emissions, stack emissions and concentrations of ultrafine particles (UFPs, diameter < 100 nm) in urban ambient air have been widely investigated for many years, indoor exposure to UFPs is a relatively new field and in order to evaluate indoor UFP emissions accurately, it is vital to improve scientific understanding of the main parameters that influence particle number, surface area and mass emissions. The main purpose of this study was to characterize the particle emissions produced during grilling and frying as a function of the food, source, cooking temperature and type of oil. Emission factors, along with particle number concentrations and size distributions were determined in the size range 0.006–20 µm using a scanning mobility particle sizer (SMPS) and an aerodynamic particle sizer (APS). An infrared camera was used to measure the temperature field. Overall, increased emission factors were observed to be a function of increased cooking temperatures. Cooking fatty foods also produced higher particle emission factors than vegetables, mainly in terms of mass concentration, and particle emission factors also varied significantly according to the type of oil used.

10/00957 Photo-oxidation of nitrogen oxide over titanium(IV) oxide modified with platinum or rhodium chlorides under irradiation of visible light or UV light

Hashimoto, K. *et al. Catalysis Today*, 2009, 144, (1–2), 37–41.

Titanium(IV) oxide samples modified with platinum or rhodium chloride (H_2PtCl_6/TiO_2 or $RhCl_3/TiO_2$) were prepared by an impregnation method and post-calcination at various temperatures and were used for photo-oxidation of nitrogen oxide under irradiation of visible light or UV light. Turnover numbers of both the catalysts were maintained at temperatures up to 350 °C under 24-h irradiation of visible light, although the specific surface area of the catalysts decreased greatly with increase in post-calcination temperature. The turnover number of H_2PtCl_6/TiO_2 was about two-times larger than that of $RhCl_3/TiO_2$. Only a small amount of released NO_2 was observed in the $RhCl_3/TiO_2$ catalyst, whereas in the H_2PtCl_6/TiO_2 catalyst, the amount of NO_2 released to gas phase increased with an increase in oxidation products. The small amount of released NO_2 indicates that most of the NOx adsorbed on $RhCl_3/TiO_2$ as an adsorption form of nonvolatile NO_3^-, whereas the amount of adsorbed NO_2 on H_2PtCl_6/TiO_2 was about four-times larger than that on $RhCl_3/TiO_2$. The results indicate that the oxidation rate of NO_2 to NO_3^- over $RhCl_3/TiO_2$ was faster than that over H_2PtCl_6/TiO_2. These results strongly suggest that the Cl radical induced by visible light was not directly related to the photo-oxidation of NO to NO_2 and NO_3^- and that the complex species of $RhCl_3$ and H_2PtCl_6 contributed to the photo-oxidation.

10/00958 Transcritical CO_2 refrigerator and sub-critical R134a refrigerator: a comparison of the experimental results

Aprea, C. and Maiorino, A. *International Journal of Energy Research*, 2009, 33, (12), 1040–1047.

This paper describes experiments comparing a commercial available R134a refrigeration plant subjected to a cold store and a prototype R744 (carbon dioxide) system working as a classical split-systems to cool air in residential applications in a transcritical cycle. Both plants are able to develop a refrigeration power equal to 3000 W. The R744 system utilizes aluminium heat exchangers, a semi-hermetic compressor, a back-pressure valve and a thermostatic expansion valve. The R134a refrigeration plant operates using a semi-hermetic reciprocating compressor, an air condenser followed by a liquid receiver, a manifold with two expansion valves, a thermostatic one and a manual one mounted in parallel, and an air cooling evaporator inside the cold store. System performances are compared for two evaporation temperatures varying the temperature of the external air running over the gas-cooler and over the condenser. The refrigeration load in the cold store is simulated by means of some electrical resistances, whereas the air evaporator of the R744 plant is placed in a very large ambient. The results of the comparison are discussed in terms of temperature of the refrigerants at the compressor discharge line, of refrigerants mass flow rate and of coefficient of performance (COP). The performances measured in terms of COPs show a decrease with respect to the R134a plant working at the same external and internal conditions. Further improvements regarding the components of the cycle are necessary to use in a large-scale split-systems working with the carbon dioxide.

10/00959 Will restrictions on CO_2 emissions require reductions in transport demand?

Johansson, B. *Energy Policy*, 2009, 37, (8), 3212–3220.

In this paper, the potential for the transportation sector to develop in a way that is consistent with long-term climate targets will be discussed. An important question is whether technical measures will be sufficient for reaching long-term climate targets. Although there is a large potential to significantly increase the use of bioenergy from today's level, there will be severe restrictions to its use within the transportation sector. Other renewable energy sources such as wind and solar are much more abundant and could provide the majority of the necessary transportation fuel in the long run. Although potentially much more expensive than current fuels they could, in combination with strong efficiency improvements, provide transport services at costs that could be acceptable in a growing economy. Transport levels as high as today or even higher could be consistent from a climate perspective if such fuels and technologies are utilized. Relying only on technical measures would, however, be risky, as there is no guarantee that the technology will develop at a sufficient rate. Furthermore, the existence of other negative environmental effects would argue for the implementation of measures affecting transport demand as well.

Hydrocarbon emissions

10/00960 Oxygenated blend design and its effects on reducing diesel particulate emissions

Wang, J. *et al. Fuel*, 2009, 88, (10), 2037–2045.

In order to meet Euro IV emission standards, diesel vehicles are compelled to install exhaust aftertreatment devices, which largely increases the overall cost. This paper explores the possibility to significantly reduce the particulate matter (PM) emissions by new fuel design. Several oxygenated blends were obtained by mixing the biodiesel, ethanol, dimethyl carbonate (DMC), and diesel fuels. The tests were conducted on two heavy-duty diesel engines, both with a high-pressure injection system and a turbocharger. The total PM and its dry soot (DS) and soluble organic fraction (SOF) constituents were analysed corresponding to their specific fuel physiochemical properties. A blended fuel that contains biodiesel, DMC, and high cetane number diesel fuels was chosen eventually to enable the diesel engines to meet the Euro IV emission regulation. Based on the test results, the basic design principles were derived for the oxygenated blends that not only need the high oxygen content, but also the high cetane number and the low sulfur and low aromatic contents.

10/00961 Size distributions of hydrocarbons in suspended particles from the Yellow River

Zhang, L. *et al. Applied Geochemistry*, 2009, 24, (7), 1168–1174.

Suspended particle samples from the Yellow River estuary were sorted into five grain size fractions to explore the effect of grain size distribution on organic matter content and composition. The *n*-alkanes and polycyclic aromatic hydrocarbons (PAHs) were determined for each size fraction. PAHs and *n*-alkanes were more abundant in the finer fractions and the loading decreases steadily with increasing of grain size. However, the total *n*-alkanes or PAHs normalized to organic C were lower in the smaller size fractions than those in the larger size fractions, suggesting *n*-alkanes or PAHs may be diluted by the addition of organic matter or gradually decreased by degradation in the smaller size fractions. The particulate *n*-alkanes in the Yellow River estuary consist of a mixture of compounds from terrigenous and riverine biogenic *n*-alkanes and more biogenic *n*-alkanes accumulate in finer particles. Particulate PAHs are related to combustion/pyrolysis processes of coal/wood, and the relative contribution of petrogenic PAHs increase with increasing grain size. The total particulate *n*-alkane and PAH discharges passing the Lijin Station are about $3.94\,\mathrm{t\,d^{-1}}$ and $0.52\,\mathrm{t\,d^{-1}}$, respectively. Fine particles ($< 32\,\mu m$) play a significant role in organic matter transfer.

Life cycle analysis

10/00962 Goodbye to carbon neutral: getting biomass footprints right

Johnson, E. *et al. Environmental Impact Assessment Review*, 2009, 29, (3), 165–168.

Most guidance for carbon footprinting, and most published carbon footprints or life cycle assessments (LCAs), presume that biomass heating fuels are carbon neutral. However, it is recognised increasingly that this is incorrect: biomass fuels are not always carbon neutral. Indeed, they can in some cases be far more carbon positive than fossil fuels. This flaw in carbon footprinting guidance and practice can be remedied. In carbon footprints (not just of biomass or heating fuels, but all carbon footprints), rather than applying sequestration credits and combustion debits, a 'carbon-stock change' line item could be applied instead. Not only would this make carbon footprints more accurate, it would make them consistent with UNFCCC reporting requirements and national reporting practice. There is a strong precedent for this change. This same flaw has already been recognised and partly remedied in standards for and studies of liquid biofuels (e.g. biodiesel and bioethanol), which now account for land-use change, i.e. deforestation. But it is partially or completely missing from other studies and from standards for footprinting and LCA of solid fuels. Carbon-stock changes can be estimated from currently available data. Accuracy of estimates will increase as Kyoto compliant countries report more land use, land use change and forestry (LULUCF) data.

10/00963 Internalization of the external costs of global environmental damage in an integrated assessment model

Kosugi, T. *et al. Energy Policy*, 2009, 37, (7), 2664–2678.

This study simulates the internalization of the external costs of major global environmental issues using an optimal economic growth model. The authors merged two existing models: an integrated assessment model (IAM) and a life-cycle impact assessment (LCIA) model. They sought to achieve simultaneously the following three objectives: (i) to incorporate environmental issues including global warming in the IAM; (ii) to assess environmental impacts with a bottom-up approach from the LCIA; and (iii) to internalize external costs obtained from the environmental impact study. The study also provides initial simulation results obtained from the merged model. Simulation results indicate that global warming will account for somewhere from 10% to 40% of all external costs in the twenty-first century. The remaining cost will come from land use and its changes. The internalization of the external cost will cause a decline in economic growth by approximately 5%, whereas forest preservation will increase by 40% and fossil-fuel consumption will be reduced by 15%. The estimated sustainability indicators imply that a necessary condition of sustainable development is satisfied for the entire world and for the developed countries during the twenty-first century, but is not satisfied until the latter half of this century for the developing counties.

16 ENERGY

Supplies, policy, economics, forecasts

10/00964 Comprehensive evaluation of household indirect energy consumption and impacts of alternative energy policies in China by input–output analysis

Liu, H.-T. *et al. Energy Policy*, 2009, 37, (8), 3194–3204.

Households consume a large amount of indirect energy through the consumption of goods and services. This fact makes the quantitative analysis of indirect household energy consumption the foundation of energy policy design. This paper improves the compilation method of energy input–output tables, and establishes a sequence of energy input–output tables for China. Based on these tables, the indirect energy consumption of both rural and urban households is calculated. Then, with economic data for the year of 2005, the adjusted input–output price model is applied to evaluate how the alternative energy policies impact production prices, consumption prices, and real income of rural and urban households through the mechanism of indirect energy consumption by using electricity as an example. This research has practical implications for Chinese economy. The integration of energy-efficiency improvements and energy prices increase serves as a means to achieve both economic and energy conservation goals, and may also have a positive effect on residents' real income and a minimal effect on production prices.

10/00965 Do LEED-certified buildings save energy? Yes, but . . .

Newsham, G. R. *et al. Energy and Buildings*, 2009, 41, (8), 897–905.

The authors conducted a re-analysis of data supplied by the New Buildings Institute and the US Green Buildings Council on measured energy use data from 100 LEED-certified commercial and institutional buildings. These data were compared to the energy use of the general US commercial building stock. They also examined energy use by LEED certification level, and by energy-related credits achieved in the certification process. On average, LEED buildings used 18–39% less energy per floor area than their conventional counterparts. However, 28–35% of LEED buildings used more energy than their conventional counterparts. Further, the measured energy performance of LEED buildings had little correlation with certification level of the building, or the number of energy credits achieved by the building at design time. Therefore, at a societal level, green buildings can contribute substantial energy savings, but further work needs to be done to define green building rating schemes to ensure more consistent success at the individual building level. Note, these findings should be considered as preliminary, and the analyses should be repeated when longer data histories from a larger sample of green buildings are available.

10/00966 Durability of 20-year-old external insulation and assessment of various types of retrofitting to meet new energy regulations

Stazi, F. *et al. Energy and Buildings*, 2009, 41, (7), 721–731.

The exterior envelope of some social housing scheme buildings constructed at the beginning of the 1970s without thermal insulation has proved to be the cause of great thermal loss and condensation. At the start of the 1980s, in order to resolve these problems, this research group carried out a study which led to the introduction of external thermal insulation (on the basis of previously developed performance specifications) and verification of the thermal performance achieved. With the aim of verifying the efficacy of the intervention after 20 years and in order to assess the thermal–hygrometric performance and the state of conservation of the exterior envelope the authors carried out a two-stage study: (1) performance analysis carried out through monitoring and laboratory tests; (2) formulation of hypotheses for retrofitting, assessed through simulations and parametric analysis. The results showed the efficacy and durability from the thermal–hygrometric and mechanical point of view of the external insulation applied in the 1980s. It was also possible to verify energy saving for the different types of retrofit scenarios and to identify the correct positioning of the thermal insulation on the brickwork and on the floors so as to increase the surface temperatures in winter phase.

10/00967 Energy consumption and economic growth: evidence from the Commonwealth of Independent States

Apergis, N. and Payne, J. E. *Energy Economics*, 2009, 31, (5), 641–647.

This study examines the relationship between energy consumption and economic growth for 11 countries of the Commonwealth of Independent States over the period 1991–2005 within a multivariate panel data framework. Based on Pedroni's heterogeneous panel cointegration test and corresponding error correction model, cointegration is present between real GDP, energy consumption, real gross fixed capital formation, and labour force with the respective coefficients positive and statistically significant. The results of the error correction model reveal the presence of unidirectional causality from energy consumption to economic growth in the short-run while bidirectional causality between energy consumption and economic growth in the long-run. Thus, the results lend support for the feedback hypothesis associated with the relationship between energy consumption and economic growth.

10/00968 Energy price-induced and exogenous technological change: assessing the economic and environmental outcomes

Kumar, S. and Managi, S. *Resource and Energy Economics*, 2009, 31, (4), 334–353.

This study distinguishes between factor/output substitution and shifts in the production technology frontier. This model includes the by-products of carbon dioxide and sulfur dioxide emissions where the function requires the simultaneous expansion of good outputs and reductions in emissions. The authors estimate a directional output distance function for 80 countries over the period 1971–2000 to measure the exogenous and oil price-induced technological change. On average, substantial oil price-induced technological progress was found at the world level when long-term oil prices are rising, although the growth rate is more volatile in developed countries than in developing countries. The results also show that developed countries experience higher exogenous technological progress in comparison with developing countries, and the gap between the two has increased during the period of our study.

10/00969 Energy sources, public policy, and public preferences: analysis of US national and site-specific data

Greenberg, M. *Energy Policy*, 2009, 37, (8), 3242–3249.

To understand public preferences for energy sources, 2701 US residents were surveyed; 2101 of the respondents lived within 50 miles of a major nuclear facility. Over 90% wanted greater reliance on solar and wind, and over 70% wanted more reliance upon hydroelectric sources. Less than one-third wanted more use of oil and coal. Nuclear and natural gas sources were closer to an even split. Notably, those who lived near nuclear facilities favoured the same sources, although a larger proportion of these respondents favoured increasing use of nuclear power than in the national sample. These results are consistent with other United States surveys. The study found striking differences in preferences by age, ethnicity/race and other demographic characteristics that need in-depth investigation in order to help decision-makers and everyone else better understand public preferences about energy policy choices.

10/00970 Greenhouse gas mitigation policies and the transportation sector: the role of feedback effects on policy effectiveness

Stepp, M. D. *et al. Energy Policy*, 2009, 37, (7), 2774–2787.

The US transportation sector is a major contributor to global greenhouse gas (GHG) emissions. As such, policymakers and stakeholder groups have proposed a number of policy instruments aimed at reducing these emissions. In order to fully evaluate the effectiveness of these policies, policymakers must consider both the direct responses associated with policy actions, and the indirect responses that occur through complex relationships within socio-economic systems. In cases where multiple policy instruments are employed, these indirect effects create policy interactions that are either complementary or competing; policymakers need to understand these interactions in order to leverage policy synergies and manage policy conflicts. Analysis of these indirect effects is particularly difficult in the transportation sector, where system boundaries are uncertain and feedback among systems components can be complicated. This paper begins to address this problem by applying systems dynamics tools (in particular causal loop diagrams) to help identify and understand the role of feedback effects on transportation-related GHG reduction policies. Policymakers can use this framework to qualitatively explore the impacts of various policy instruments, as well as identify important relationships that can be later included in quantitative modelling approaches.

10/00971 Growth and structural change in China's energy economy

Kahrl, F. and Roland-Holst, D. *Energy*, 2009, 34, (7), 894–903.

China has been the world's most vibrant economy and its largest source of energy demand growth over the past two decades, accounting for more than one-quarter of net growth in global primary energy consumption from 1980 to 2005. To sustain economic growth and rising living standards, China needs effective policies that anticipate and shape the country's future energy requirements. This study examines China's national economic and energy accounts over the past decade for insights into changing energy use patterns and their relationship to economic structure. The results indicate that incipient structural changes in the Chinese energy economy and sustained economic and energy demand growth in China will pose important, and different, challenges for policymakers.

10/00972 Likelihood of meeting the EU limit values for NO$_2$ and PM$_{10}$ concentrations in the Netherlands

Velders, G. J. M. and Diederen, S. M. A. *Atmospheric Environment*, 2009, 43, (19), 3060–3069.

In 2007, the European limit values for annual average nitrogen dioxide (NO$_2$) concentration and for daily average particulate matter (PM$_{10}$) concentration were exceeded along motorways and city streets in the Netherlands. While the road length along which the exceedance occurred is uncertain, model calculations show that the NO$_2$ concentration was likely to have been exceeded (chance >66%) along about 300 km and PM$_{10}$ concentration along about 75 km. In addition, the limit values were exceeded 'about as likely as not' (chance 33–66%) along a total of 1000 km for NO$_2$ and 1600 km for PM$_{10}$. PM$_{10}$ and NO$_2$ concentrations must be below the limit values everywhere in Europe, ultimately by 2011 and 2015, respectively. Since estimates of future local concentrations have an uncertainty of about 15–20%, no absolute statements can be made whether concentrations will be below the limit values within the specified time. Model calculations accounting for the effects of current and proposed national and European legislation, and using average meteorology for large-scale and local traffic contributions show strong decreases in likely limit value exceedances in the Netherlands. However, limit value exceedances are still possible (chance >33%) along about 350 km for PM$_{10}$ by 2011, and about 150 km for NO$_2$, by 2015. These possible exceedances depend not only on the uncertainties and on national and European policies and their effectiveness, but also on contributions by specific additional local measures. The Netherlands government has proposed a plan, which includes local measures to meet the limit values everywhere, in time. Although not assessed here due to their specific character, such local measures could reduce exceedances. As the effects of local measures and estimates of concentrations are uncertain, continuous monitoring – possibly together with additional measures – will be needed to adhere to the limit values.

10/00973 Taxes, permits, and the diffusion of a new technology

Coria, J. *Resource and Energy Economics*, 2009, 31, (4), 249–271.

This study looks at the effects of the choice between taxes and permits on the pattern of adoption of a new (pollution) emissions abatement technology. It uses a dynamic setting, where the regulator observes the arrival and initial use of the technology and determines the optimal *ex post* amount of emissions before firms start to adopt the technology. In the model here, the adoption benefits and costs depend on the number of firms that are already using the technology. Thus, each firm decides the optimal date to adopt the technology, considering its benefits and costs, as well as the advantage they will gain over their rivals, producing a sequence of adoption that is 'diffused' into the industry over time. With this framework, the study shows that when the output demand is elastic, auctioned permits induce an earlier diffusion than taxes.

10/00974 The effect of the German and British environmental taxation reforms: a simple assessment

Agnolucci, P. *Energy Policy*, 2009, 37, (8), 3043–3051.

This article implements a simple econometric approach to assess the effect of the environmental tax reforms introduced in Germany and the UK. Despite the very simple econometric approach adopted in this paper, in the case of the energy demand, these results do not differ markedly from those obtained from complicated multi-sectoral econometric models. In the case of the labour demand, the results differ from the estimates obtained from econometric models where the employment level is not directly influenced by the energy price. On the other hand, the results are more similar to those obtained from models where the level of employment is directly influenced by the energy price. Confirming the findings of Bosquet and the OECD, it was concluded that environmental tax reforms can deliver substantial reductions in energy consumption while having small effects on the level of employment, effect which can be positive, depending on the size of the reduction in the labour costs and the value of cross-price elasticities.

10/00975 The forecast of motor vehicle, energy demand and CO$_2$ emission from Taiwan's road transportation sector

Lu, I. J. *et al. Energy Policy*, 2009, 37, (8), 2952–2961.

The grey forecasting model, GM(1,1) was adopted in this study to capture the development trends of the number of motor vehicles, vehicular energy consumption and CO$_2$ emissions in Taiwan during 2007–2025. In addition, the simulation of different economic development scenarios were explored by modifying the value of the development coefficient, *a*, in the grey forecasting model to reflect the influence of economic growth and to be a helpful reference for realizing traffic CO$_2$ reduction potential and setting CO$_2$ mitigation strategies for Taiwan. Results showed that the vehicle fleet, energy demand and CO$_2$ emitted by the road transportation system continued to rise at the annual growth rates of 3.64%, 3.25% and 3.23% over the next 18 years. Besides, the simulation of different economic development scenarios revealed that the lower and upper bound values of allowable vehicles in 2025 are 30.2 and 36.3 million vehicles, respectively, with the traffic fuel consumption lies between 25.8 million kilolitres to 31.0 million kilolitres. The corresponding emission of CO$_2$ will be between 61.1 and 73.4 million metric tons in the low- and high-scenario profiles.

10/00976 Use and limitations of learning curves for energy technology policy: a component-learning hypothesis

Ferioli, F. *et al. Energy Policy*, 2009, 37, (7), 2525–2535.

This study investigates the use of learning curves for the description of observed cost reductions for a variety of energy technologies. The starting point of this analysis is the representation of energy processes and technologies as the sum of different components. While the authors recognize that in many cases 'learning-by-doing' may improve the overall costs or efficiency of a technology, they argue that so far insufficient attention has been devoted to study the effects of single component improvements that together may explain an aggregated form of learning. Indeed, for an entire technology the phenomenon of learning-by-doing may well result from learning of one or a few individual components only. The authors analyse under what conditions it is possible to combine learning curves for single components to derive one comprehensive learning curve for the total product. The possibility that for certain technologies some components (e.g. the primary natural resources that serve as essential input) do not exhibit cost improvements might account for the apparent time dependence of learning rates reported in several studies (the learning rate might also change considerably over time depending on the data set considered, a crucial issue to be aware of when one uses the learning curve methodology). Such an explanation may have important consequences for the extent to which learning curves can be extrapolated into the future. This argumentation suggests that cost reductions may not continue indefinitely and that well-behaved learning curves do not necessarily exist for every product or technology. In addition, even for diffusing and maturing technologies that display clear learning effects, market and resource constraints can eventually significantly reduce the scope for further improvements in their fabrication or use. It appears likely that some technologies, such as wind turbines and photovoltaic cells, are significantly more amenable than others to industry-wide learning. For such technologies the reliability is assessed of using learning curves at large to forecast energy technology cost reductions.

Energy conservation

10/00977 Cooling load reduction of building by seasonal nocturnal cooling water from thermosyphon heat pipe radiator

Chotivisarut, and Kiatsiriroat, T. *International Journal of Energy Research*, 2009, 33, (12), 1089–1098.

In this study, a concept of using thermosyphon heat pipe to extract heat from water in a storage tank to generate cooling water was proposed. Heat pipe condenser was attached with an aluminum plate and acted as a thermal radiator while its evaporator was dipped in the water storage tank. Cooling water in the tank could be produced during the nighttime and used to serve the cooling load in a room during the daytime. A heat transfer model to calculate the water temperature and the room temperature during both the nighttime and daytime was developed. The input data were ambient temperature, dew point temperature, area of the radiator, volume of cooling water and room cooling load. The experiment was setup to verify the heat transfer model. A 9.0 m^2 tested room with six cooling coils, each of 0.87 m^2 was installed at the ceiling, was constructed along with the 1.0 m^3 water storage tank. A 500–2000 W adjustable heater was taken as an artificial load inside the room. A 6.36 m^2 radiator is installed on a 45° tilting roof of the tested room. The simulated results agreed very well with those of the experimental data. With the developed model, a simulation to find the sizing of the radiator area and the volume of cooling water for cooling water production during winter of Chiang Mai, Thailand was carried out. The cooling water was used for cooling during summer in an air-conditioned room with different cooling loads. The parameters in terms of room temperature, radiator area, volume of cooling water, cooling load and UA of cooling coil were considered to carry out the percent of cooling load reduction.

10/00978 Effects of connection of electrical and mechanical potentials in inverse osmosis processes

Cortés, F. *et al. Energy Conversion and Management*, 2009, 50, (7), 1841–1846.

A theoretical dissertation and experimental assays of the irreversible phenomena applied to electro-kinetics and inverse osmosis is presented. Experimental assays were made on simple equipment to evidence the occurrence of connected irreversible phenomena between electric current flow and global mass flow. The coupling of these two phenomena allowed us to make conclusions about the possibility of reducing operation costs of the inverse osmosis equipment due to increasing the saline solution flow between 12% and 20%.

10/00979 Energy resources' utilization in organic and conventional vineyards: energy flow, greenhouse gas emissions and biofuel production

Kavargiris, S. E. *et al. Biomass and Bioenergy*, 2009, 33, (9), 1239–1250.

An energy analysis, in conventional and organic vineyards, combined with ethanol production and greenhouse gas emissions, is useful in evaluating present situation and deciding best management strategies. The objective of this study was to evaluate the differences in the energy flow between organic and conventional vineyards in three locations, to calculate CO_2, CH_4 and N_2O-emissions based on the used fossil energy and to explore if wine industry wastes can be used to extract bioethanol. The data were collected through personal interviews with farmers during 2004–2005. Eighteen farmers, who owned vineyards about 1 ha each, were randomly selected to participate in this study [(three conventional and three organic) × three locations]. The means averaged over all locations for fertilizer application, plant protection products application, transportation, harvesting, labour, machinery, fuels, plant protections products and tools energy inputs, total energy inputs, outputs (grapes), outputs (grapes + shoots), grape yield, man hour, pomace and ethanol from pomace were significantly higher in conventional than in organic vineyards, while the opposite occurred for the pruning. Means averaged over two farming systems for harvesting, tools energy inputs, energy outputs (grapes), grape yield, pomace and ethanol from pomace were significantly higher at location A, followed by location C and location B. Finally, for irrigation, the means averaged over the two farming systems were significantly lower at location C. Greenhouse gas emissions were significant lower in organic than in conventional vineyards. The results show a clear response of energy inputs to energy outputs that resulted from the farming system and location.

10/00980 Experimental study of the energy efficiency of an incinerator for medical waste

Bujak, J. *Applied Energy*, 2009, 86, (11), 2386–2393.

The aim of this paper is to explore the flux of usable energy and the coefficient of energy efficiency of an incinerator for medical waste combustion. The incineration facility incorporates a heat recovery system. The installation consists of a loading unit, a combustion chamber, a thermoreactor chamber, and a recovery boiler. The analysis was carried out in the Oncological Hospital in Bydgoszcz (Poland). The primary fuel was comprised of medical waste, with natural gas used as a secondary fuel. The study shows that one can obtain about 660–800 kW of usable energy from 100 kg of medical waste. This amount corresponds to 1000–1200 kg of saturated steam, assuming that the incinerator operates at a heat load above $\varphi > 65\%$. The average heat flux in additional fuel used for incinerating 100 kg of waste was 415 kW. The coefficient of energy efficiency was set within the range of 47% and 62% depending on the incinerator load. The tests revealed that the flux of usable energy and the coefficient of energy efficiency depend on the incinerator load. In the investigated range of the heat load, this dependence is significant. When the heat load of the incinerator increases, the flux of usable energy and the coefficient of energy efficiency also increase.

10/00981 Heat fluxes through roofs and their relevance to estimates of urban heat storage

Meyn, S. K. and Oke, T. R. *Energy and Buildings*, 2009, 41, (7), 745–752.

The storage heat flux constitutes a large term in the heat balance of cities. This flux is difficult to measure but one approach is to parameterize it using relations between the net all-wave radiation and the heat flux conducted into and out of the typical materials that form the surface of cities and combine them into a weighted average to give the bulk storage. Urban heat storage parameterization could be improved if there were more and better estimates of the net radiation vs storage relation for typical urban and suburban roofs. This paper presents the results of a study of the heat storage characteristics of six different roof assemblies (typical of many North American commercial/industrial and residential buildings) in Vancouver, Canada, observed across a range of wind and moisture conditions. Further, these observations are used to verify the simplified transient analysis of roofs (STAR) model, which is then used to estimate the heat storage parameterization for other roof types, thereby extending the usefulness of the scheme to a wider range of urban areas.

10/00982 Improving energy recovery for water minimisation

Leewongtanawit, B. and Kim, J.-K. *Energy*, 2009, 34, (7), 880–893.

A graphical approach for the design of heat-integrated water systems has been proposed to improve conceptual understanding for implications of heat recovery in water systems, as well as to provide systematic design guidelines for selecting most appropriate integrated options in practice. The developed design method aims to fully exploit water reuse potentials between water-using operations, and simultaneously to minimize any potential degradation of energy recovery resulted from water reuse. Graphical representations of heat-integrated water systems and their manipulation have been applied to investigate systematically design interactions, impacts associated with stream merging and splitting, and influences of non-isothermal mixing on heat recovery. A water energy balance diagram has been developed to improve energy recovery in water reuse network. Energy-efficient and cost-effective configuration for heat recovery has been identified, using improved separate system approach. The proposed approach significantly reduces both water and energy requirements for single-contaminant water systems.

10/00983 Long-term performance of high-reflectivity exterior panels

Ichinose, M. *et al. Building and Environment*, 2009, 44, (8), 1601–1608.

Paint performance was assessed over time with respect to surface contamination and degradation of reflectivity through environmental exposure tests. Test panels were coated with high-reflectivity or conventional paints. One set of test panels was coated with high-reflectivity paint on site or in-factory at the manufacturing stage by a newly developed heat curing paint method. Following environmental exposure, this heat curing paint method was evaluated for its long-term performance in thermal conditioning, and durability, as well as for possible performance enhancement with the addition of a photocatalyst. Solar reflectivity of the panels was degraded by exposure to ultraviolet light, adhesion of airborne contaminants, and exposure to high temperatures and precipitation. Newly developed high-reflectivity heat curing paint was just as durable as conventional heat curing paint. In addition, panels coated with a photocatalyst in-factory achieved a high level of solar reflectivity for a longer period compared to panels coated with conventional paint in-factory and high-reflectivity paint on site.

10/00984 Negative rebound and disinvestment effects in response to an improvement in energy efficiency in the UK economy

Turner, K. *Energy Economics*, 2009, 31, (5), 648–666.

This paper uses a computable general equilibrium (CGE) framework to investigate the conditions under which rebound effects may occur in response to increases in energy efficiency in the UK national economy. Previous work for the UK has suggested that rebound effects will occur even where key elasticities of substitution in production are set close to zero. The research reported in this paper involves carrying out a systematic sensitivity analysis, where relative price sensitivity is gradually introduced into the system, focusing specifically on elasticities of substitution in production and trade parameters, in order to determine conditions under which rebound effects become a likely outcome. The main result is that, while there is positive pressure for rebound effects even where (direct and indirect) demands for energy are very price inelastic, this may be partially or wholly offset by negative income, competitiveness and disinvestment effects, which also occur in response to falling energy prices. The occurrence of disinvestment effects is of particular interest. These occur where falling energy prices reduce profitability in domestic energy supply sectors, leading to a contraction in capital stock in these sectors, which may in turn lead to rebound effects that are smaller in the long run than in the short run, a result that runs contrary to the predictions of previous theoretical work in this area.

10/00985 Optimal design method for building energy systems using genetic algorithms

Ooka, R. and Komamura, K. *Building and Environment*, 2009, 44, (7), 1538–1544.

In this paper, a new optimal design method for building energy systems is proposed. This method provides the most efficient energy system, best combination of equipment capacity and best operational planning for cooling, heating, and power simultaneously with respect to certain criteria such as energy consumption, CO_2 emission, etc. Specifically for this paper, the authors apply this method to a sample building as a case study. The 'genetic algorithms (GA)' optimization method, which can resolve non-linear optimization problems, is adopted for this optimization analysis. Also its applicability is analysed in a case study. In order to validate the accuracy of this method, the correct optimum solution based on comprehensive inquiries is also calculated. A comparison of the GA solution with the correct solution demonstrates fairly good agreement. The results show that the proposed method is sufficiently capable of determining the optimal design and has the potential to be applied to very complex energy systems with appropriate modifications.

10/00986 Optimizing CO_2 avoided cost by means of repowering

Escosa, J. M. and Romeo, L. M. *Applied Energy*, 2009, 86, (11), 2351–2358.

Repowering fossil fuel power plants by means of gas turbines has been traditionally considered to increase power output and reduce NO_x and SO_2 emissions both at low cost and short outage periods. At present, reduction in CO_2 emissions represents an additional advantage of repowering due to partial fuel shift and overall efficiency increase. This is especially important in existing installations with a CO_2 reduction mandatory that should be carried out in a short time and in a cost-effective manner. Feedwater and parallel repowering schemes have been analysed using thermodynamic, environmental and economic simulations. The objective is not only to evaluate the cost of electricity and the efficiency increase of the overall system, but calculate and minimize the cost of CO_2 avoided as a function of gas turbine power output. It seems that integration of larger gas turbines reduces the overall CO_2 emissions, but there is a compromise between CO_2 reduction due to fuel shift and a optimum integration of waste heat into the power plant to minimize the CO_2 avoided costs. Results highlight the repowering as a suitable technology to reduce 10–30% of CO_2 emissions in existing power plants with cost well below 20 €/tCO_2. It could help to control emissions up to the carbon capture technologies commercial development.

10/00987 Research on energy-saving effect of technological progress based on Cobb–Douglas production function

Yuan, C. *et al. Energy Policy*, 2009, 37, (8), 2842–2846.

Energy issues receive more and more attention these days. And it is considered that technological progress is an essential approach to save energy. This essay is to analyse the relation between energy intensity and technological progress by Cobb–Douglas production function in which energy, labour, capital and technological progress are taken as independent variables. It proves that the growth of output per capital and output per labour will increase energy intensity while technological progress will decrease energy intensity. Empirical research on Chinese industry is used here to indicate technological progress greatly decreases energy intensity. Because of the interferences of Asian financial crisis, there is something abnormal in the data. So in the empirical research, average weaken buffer operator (ABWO) is applied to weaken the interference of Asian financial crisis to the fixed assets, energy and value added. The results of the empirical research show that technological progress decreases energy intensity of Chinese industry an average of 6.3% every year in China.

10/00988 Research on the energy-saving effect of energy policies in China: 1982–2006

Yuan, A. *et al. Energy Policy*, 2009, 37, (7), 2475–2480.

This paper summarizes the main energy policies of China from 1980, and divides them into three groups of policies. Two methods, with and without antitheses and linear regression, are created to evaluate the energy-saving effects of the energy policies. And the energy-saving effects of these three groups of energy policies of China are evaluated by the two methods, respectively. It is concluded that with and without antitheses is used to evaluate short-term effects and linear regression is used to evaluate long-term effects.

10/00989 The market for green building in developed Asian cities – the perspectives of building designers

Chan, E. H. W. *et al. Energy Policy*, 2009, 37, (8), 3061–3070.

Green building (GB) is part of the concept of promoting sustainability. Although GB and the concept of sustainability are well studied for environmental concerns, their business rationale and related social concerns have not been fully explored or widely accepted by the parties involved in the building sector. In this study, the situation of GB market in relation to the general building market is reviewed and the business rationales of stakeholders to invest in the GB market have been investigated from the perspective of building designers. In addition, the factors that enhance the popularity of GB have been explored and the obstacles that hinder its market have been examined. The data are collected by a questionnaire survey covering building designers in Hong Kong and Singapore, the cities that are categorized as economically developed cities in Asia. After data analysis of the survey, this paper presents the findings of the business reasons for stakeholders to be involved in GB, the most favourable conditions required to promote GB business and the important obstacles that hinder its popularity. Based on the findings, recommendations and policy implications are tendered.

10/00990 Thermal performance of a small oil-in-glass tube thermal energy storage system during charging

Mawire, A. *et al. Energy*, 2009, 34, (7), 838–849.

A very small oil-in-glass tube thermal energy storage (TES) system is designed to allow for rapid heat transfer experiments. An electrical hot plate in thermal contact with a steel spiral coil (SSC) is used to charge the TES system under different hot plate temperatures and under different average charging flow rates. Thermal performance during charging is presented in terms of the axial temperature distribution, the axial degree of thermal stratification, the total energy stored and the total exergy stored. The energy and exergy delivery rates of the energy delivery device (EDD) are also evaluated in relation to the thermal performance of the storage system. Results of charging the storage system under different hot plate temperatures indicate that there is an optimal charging temperature for optimal thermal performance. The results also indicate that exceeding this optimal temperature leads to a degradation of the thermal performance due to increased heat losses. Charging at the same temperature conditions under different flow rate regimes suggests that there is an optimal charging flow rate. This optimal flow rate is a compromise between achieving a greater heat transfer rate in the EDD and achieving a greater degree of thermal stratification in the TES system.

17 ENERGY CONVERSION AND RECYCLING

10/00991 Combustion characteristics of sewage sludge in an incineration plant for energy recovery

Murakami, T. *et al. Fuel Processing Technology*, 2009, 90, (6), 778–783.

A new type of sewage sludge incinerator that combines a pressurized fluidized bed combustor and a turbocharger driven by flue gas was proposed. In this study, the operation and combustion characteristics of a demonstration plant were clarified, and the design data for a commercial plant were obtained. The steady operation exceeded 600 h in total. CO, NO_x, and N_2O emissions in the flue gas were less than half those of a conventional plant. At an incineration capacity of 100 t/day, an energy savings of approximately 50% can be achieved compared with a conventional plant because the forced draft fan (FDF), the induced draft fan (IDF) and the feed water pump are unnecessary. Also, pressurization allowed reduction of the combustor volume, so about 25% of supplementary fuel can be reduced. Consequently, CO_2 emissions originating from electric power consumption and supplementary fuel is expected to be reduced by about 40% annually compared with emissions from a conventional plant; in addition, the cost of fuel and electricity can be reduced by 23 million yen. Therefore, this advanced incinerator for sewage sludge can realize energy recovery and savings as well as a low environmental impact.

10/00992 Conversion of waste rubber to the mixture of hydrocarbons in the reactor with molten metal

Stelmachowski, M. *Energy Conversion and Management*, 2009, 50, (7), 1739–1745.

Scrap tyres are the source of renewable energy and raw chemical products for the refinery, petrochemical and rubber industry. The results of thermal degradation of waste rubber performed in a new type of a tubular reactor with the molten metal bed are presented in the paper. The melting and degradation processes were carried out in one apparatus at the temperature 390–420 °C. The time of the described conversion process is shorter than the time of catalytic cracking or pyrolysis performed in classical batch or continuous flow reactors. The process was carried out in the inside of the molten metal bed and on its surface. The problems encountered with: the disintegration of wastes, the heat transfer from the wall to the particles, cooking at the walls of the reactor, and mixing of the molten volume of wastes are significantly reduced. Three products: the gaseous (below 14 wt.%), liquid (over 41 wt.%) product and solid residue were obtained during the degradation of waste rubber. The streams of gaseous and liquid products were analysed by gas chromatography. The gaseous stream contained hydrocarbons from C_2 to C_8 and the liquid product consisted of hydrocarbons C_4–C_{24}. Over 75 mol% of liquid hydrocarbons mixture was the fraction C_4–C_{10}. The obtained liquid product may be used in petrochemical and refinery industry for fuel production.

10/00993 Evaluation of the performance of biodiesel from waste vegetable oil in a flame tube furnace

de Souza, G. R. *et al. Applied Thermal Engineering*, 2009, 29, (11–12), 2562–2566.

This work presents a theoretical and experimental study of the biodiesel (ethyl ester from a waste vegetable oil) performance in a flame tube furnace. The heat transfer rate was analysed in several sections along the furnace and the performance of the biodiesel was compared to that of diesel oil. The flow of heat from the burn of each fuel in the direction of the walls of the combustion chamber was evaluated under the same fuel injection pressure. The peak of the heat transfer occurred around 0.45 m far from the fuel injection nozzle in a 0.305 m inner diameter combustion chamber. The diesel oil showed a higher heat transfer rate in most parts exposed to the flame. In the region where the body of the flame is not present, the heat transfer of biodiesel becomes higher.

10/00994 Exploitation of olive oil mill wastewater for combined biohydrogen and biopolymers production

Ntaikou, I. *et al. Bioresource Technology*, 2009, 100, (15), 3720–3730.

The present study aimed to the investigation of the feasibility of the combined biohydrogen and biopolymers production from OMW (olive oil mill wastewater), using a two stage system. H_2 and volatile fatty acids (VFAs) were produced via anaerobic fermentation and subsequently the acidified wastewater was used as substrate for aerobic biodegradable polymer production. Two different bioreactors, one of CSTR type and a SBR were used for the anaerobic and the aerobic process respectively. The anaerobic reactor was operated at different hydraulic retention times (HRTs) with OMW, diluted 1:4 (v/v) with tap water, as feed. The main VFAs produced were acetate, butyrate and propionate, in different ratios depending on the HRT. Valerate, isovalerate and isobutyrate were also detected in small quantities. Selective effluents of the acidogenic/hydrogen producing reactor were subsequently used as feed for the aerobic reactor. The aerobic reactor was inoculated with an enriched PHAs producing bacteria culture, and was operated in sequential cycles of nitrogen offer (growth phase) and nitrogen limitation (PHAs accumulation phase). The operational program of the SBR was determined according to the results from batch test, and its performance was evaluated for a period of 100 days. During the accumulation phase butyrate was consumed preferably, indicating that the dominant PHA produced is polyhydroxybutyrate. The higher yield of PHAs observed was 8.94% (w/w) of dry biomass weight.

10/00995 Feedstock recycling of plastic wastes/oil mixtures in cokemaking

Diez, M. A. *et al. Fuel*, 2009, 88, (10), 1937–1944.

Two lubricating oils, a plastic waste composed mainly of polyolefins (95%) and their mixtures (1:1 w/w) were assessed for possible use as minor components of coal blends for metallurgical coke production. The addition of 2 wt% plastic waste causes a decrease in the maximum fluidity of the coal developed during thermal heating between 400 and 500 °C. At the same addition rate, the two oils are good additives for mixing with coal/plastic blends in order to partially restore the caking ability of the co-carbonizing systems. Co-carbonizations of the coking blend with the different wastes were carried out in a movable wall oven of 15 kg capacity. Although the bulk density remained unchanged, the addition of the plastic waste produced an increase in coking pressure to values that were too high for it to be considered as a safe blend. At the same time the mechanical strength of the partially gasified coke was improved as reflected by the CSR index. The oils, however, had the effect of reducing bulk density and the coking pressure generated during the process. When blended with the coal and the plastics, the oils appeared to act as good solvents of the polyolefins and also proved to be effective in decreasing coking pressure without negatively affecting coke quality.

10/00996 Quantification and use of forest biomass residues in Maputo province, Mozambique

Vasco, H. and Costa, M. *Biomass and Bioenergy*, 2009, 33, (9), 1221–122.

This article describes a study on the quantification and use of forest biomass residues in Maputo province, in Mozambique. The study was performed based on information from the thematic cartography of soils of Maputo province, provided by the National Direction of Forest and Land of Mozambique, and data for the forest growth rates available in the literature. It was estimated that the total production of forest biomass residues in Maputo province is 1,233,412 ton/year, with a corresponding energy potential of 17,267,771 GJ/year. As a way of making the forest biomass residues profitable, the present work proposes the use of part of the residues as fuel in new power plants to be build in Maputo province. In this part of the study aiming at implanting power plants in Maputo province, it was taken into account the risk of forest fires, number of existing consumers of forest residues, residues availability, protected forests, transport infrastructures and existence of national electric network. It was found that the districts of Magude and Moamba are those that have the best conditions to receive the new biomass power plants. Factors such as the cost of the technology and the degree of pre-treatment of the forest residues have been taken into consideration in choosing the combustion technology for the proposed power plants. In this context, the grate burning technology appears to be the most advantageous from costs/benefits viewpoint. The proposed power plants can produce about 236,520 MWh, which is equivalent to 32% of the energy consumed in Maputo province in 2004.